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PROCEEDINGS OF THE 34TH SOUTHERN PASTURE AND FORAGE CROP IMPROVEMENT CONFERENCE

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FORAGES IN ALABAMA

By Donald M. Ball

It's my pleasure to welcome you to Alabama and to have the opportunity to tell you a little about forage production here. The first thing I'd like to tell you is that forages are an important agricultural commodity in Alabama. As you know, it's difficult to estimate the value of forages since they're not sold directly as other crops are. However, an indication of their importance in Alabama is the fact that our beef and dairy industries gross well over 200 million dollars annually. Of course, forages also supplement the diets of other farm animals, they have conservation value, etc. In short, there is no question but that forages have a tremendous impact on Alabama's economy.

Forages are also important from the standpoint that they occupy a significant portion of Alabama's land area. We estimate that we currently have over four million acres of improved pasture and other forage crops - that's about 55% of the non-forested agricultural land in the state. If we included rangeland, this figure would be considerably higher.

Although time won't permit me to describe in detail the various environments we have for growing forages in various parts of the state, I can assure you that there are wide variations in soils, and there are also considerable variations in rainfall and temperature in various parts of the state. Not surprisingly then, there are many different forage species which are adapted to be grown in Alabama.

Perhaps the most meaningful way to quickly orient you to Alabama agriculture is to describe the various agricultural regions of the state. These regional classifications to which I'll refer are based partially on soils and climate, partially on topography, and partially on agricultural land use.

In the north central part of the state, we have what we refer to as our Limestone Valley or Tennessee Valley region. The soils in this area are predominantly red clay loams. Most of the land is open, and it's an area of intensive row-cropping. Over half the state's cotton is produced in the Limestone Valley area. Corn and soybeans are also important.

Our Sand Mountain region is in the northeastern part of the state, and as the name implies, there is some rugged terrain in this area. Many plateau areas also exist, however, which contain highly responsive fine sandy loam soils. Corn, poultry, and various vegetable crops are important in this region. Many of our dairy producers are located in this area also.

In the east-central part of the state is an area of rolling or rugged terrain which we call our Piedmont area. This section, which mostly contains red clay loam soils, at one time supported a large cotton acreage. Unfortunately, much erosion took place during this period of row-cropping. In the past two decades, much of the Piedmont area has been returned to woodlands or put into pasture.

The Upper Coastal Plain stretches from east to west across the central and into the northwestern parts of Alabama, and is an area in which timber is an important commodity. Most farmland in this area is either along streams or on rolling ridge tops. There is a diversity of agricultural interests in the region.

The Black Belt is a unique area stretching from east to west across the state which contains many montmorillonitic soils. These vary from being red, acid clays to being black, calcareous prairie soils. This is the area of the greatest beef cattle density in the state. Soybeans are also important in the Black Belt.

The Wiregrass area in the southeastern corner of Alabama contains many deep, sandy soils, and is an area of much row-crop activity. Peanuts are the main cash crop, but corn and swine are also important.

The area in southwest Alabama which we refer to as our Lower Coastal Plain is much like the Wiregrass area as far as soils and climate are concerned, but farming is not as intensive in this area. Much of the western part of this area is used for timber production, although soybeans, corn and beef cattle are also important.

Last but not least is our Gulf Coast area. This is an area of good farmland and the most intensive agricultural production in the state. Double-cropping is extensive in this region, and the main agricultural enterprises are horticultural crops, grain crops, and beef cattle. Now that you have in mind the main agricultural areas of the state, let's consider the main forage species used in Alabama.

The forage species of which there is more acres than any other in Alabama is tall fesue - most of which is in the northern half of the state. We estimate that we have around one million acres of tall fescue, and essentially all of this is the variety 'Kentucky 31'. Varieties which are better adapted to the southern half of the state would be useful.

We also have around 900,000 acres of bahiagrass. Although bahiagrass was only introduced into Alabama a little over two decades ago, it is now by far the predominant pasture species in the southern half of the state. Most of our bahiagrass acreage is the variety 'Pensacola' although 'Argentine' is increasing in popularity in the southern third of the state.

Bermudagrass is also an important forage species used both for grazing and hay. We estimate that we have around 650,000 acres, of which around 350,000 acres is 'Coastal.' There is a tremendous amount of interest among producers in new bermudagrass varieties and, although some varieties can only be grown in some areas, bermudagrass of one variety or another can be grown in every county in the state.

Another important perennial grass species is dallisgrass. Although dallisgrass generally doesn't yield as much as other warm-season perennials, it tends to compensate for this in that the forage is relatively good quality. We have around 400,000 acres of dallisgrass - most of this is in the Black Belt, although it can be grown in other areas of central and north Alabama.

Johnsongrass is also grown primarily in the Black Belt and is used primarily for hay production. Johnsongrass makes very good quality hay if handled properly. We estimate we have around 100,000 acres of this species.

Orchardgrass is grown almost exclusively in the northern third of the state. Although we appreciate the relatively high quality of orchardgrass forage, we have problems with persistence - this is particularly true the further south one goes in the state. Orchardgrass is frequently "crowded out" by tall fescue and we only have around 25,000 acres in which it is the predominant species.

As far as perennial legumes are concerned, white clover is certainly one of our most valuable species. Ladino is the most productive type, and 'Regal' is the most popular variety. We estimate we have around 100,000 acres which contain a significant amount of white clover, and in areas where it's grown, it is almost always used as a companion species to either fescue, orchardgrass, or dallisgrass.

Another important perennial legume is sericea lespedeza. Most of our sericea acreage is on rolling or hilly land in the north and central parts of the state, and we have around 180,000 acres devoted to this species. Since the release of the improved varieties 'Serala' and 'Interstate,' there has been renewed interest in growing sericea in Alabama.

We currently have only a few thousand acres of alfalfa. Most of this is either in the Limestone Valley area or on the high pH Black Belt soils. There is a considerable amount of interest in growing alfalfa, however, and it seems likely that the acreage will increase in the next few years.

Although we do not have any appreciable acreage of summer annual legumes, we do have an estimated 175,000 acres of summer annual grasses. Most of this is planted to either sorghum-sudan hybrids or pearlmillet. We only have around 15,000 acres of silage corn, and less than 5,000 acres of silage sorghum. Most of our silage is used in dairy operations.

I've saved for last the area of forage production which is currently creating the greatest amount of enthusiasm among producers. I'm referring to our winter annual forage species.

When we talk about winter annual forages in Alabama, we're basically talking about some combination of three types of plants: (1) small grain - usually either rye or wheat; (2) annual ryegrass; and (3) annual clover - usually either crimson or arrowleaf clovers. We estimate that we have some 600,000 acres devoted to winter annual grazing crops, and the acreage is increasing. These species are particularly important to us, because they give the Alabama producer the advantage of being able to provide high-quality grazing during even some of the coldest months of the year. In Alabama, winter annuals are mostly used in stocker calf and dairy programs. Mixtures of winter annuals provide high-quality grazing over an extended period of time. The release of arrowleaf clover has been particularly important for Alabama producers because it allows extension of the winter grazing period to late May or June.

I certainly don't want to mislead you - we have our share of problems with forage production in Alabama. One big problem is weed control. Another problem is inadequate fertilization and liming. Still another problem is that many producers show little concern about the quality of stored forages. We also have other problems which we are trying to overcome.

I'd like to conclude this review of forage production in Alabama by discussing the most impressive part of the Alabama forage picture. I'm referring to the fact that Alabama has tremendous unrealized forage production potential. We have potential for increasing the productivity of existing forage crop acreage, and we also have much potential for expansion of acreage.

At the present, approximately 65% of Alabama's land area is in woodlands. It's reasonable to believe that eventually much of this woodland, most of which is not suitable for row-crop production, will be utilized for forage production.

In summary, because we have a mild climate and good rainfall which are conducive to the growth of forages throughout most of the year, because we have land available for expansion of forage crop acreage, and because we have a progressive forage research program here at Auburn University, we're optimistic about the future of forage production in Alabama!

FORAGE BREEDING HIGHLIGHTS
AT AUBURN (ALA.) AGRICULTURAL EXPERIMENT STATION

By Wiley Johnson

Sericea

Following the development of low tannin sericea germplasm (Beltsville 23-864) by USDA personnel at Beltsville, Md., sericea with a desirable plant type and low tannin content was developed at Auburn by Dr. E. D. Donnelly. This was accomplished using the backcross method with normal high tannin sericea as the recurrent parent and with progeny testing and selection for low tannin following each backcross. The resulting low tannin sericea was found to be extremely susceptible to Rhizoctonia. Extensive testing and selection, however, has demonstrated that susceptibility to Rhizoctonia was largely a case of close linkage with low tannin and not pleitropy. Linkage has been broken and Rhizoctonia resistant, low tannin, vigorous selections have been identified.

Extensive cooperative research involving Dr. Donnelly and Dr. Norman Minton of the USDA at Tifton, Ga. has been conducted to develop sericea varieties resistant to root-knot nematodes. Two varieties, Serala 76 and Interstate 76, which have a high level of resistance to most common strains of root-knot nematodes have recently been released.

Vetch

Recent emphasis in vetch breeding has been to develop varieties combining the characteristics of hard seed, vigorous winter production, and cold hardiness. Selection in the advanced generations of interspecific hybrids of *Vicia sativa* x *V. cordata* and *V. sativa* x *V. serratifolia* has resulted in the recent release of the following *V. sativa* (common vetch) type varieties: Nova II, Cahaba White, Vantage and Emerald.

Cool season perennial grasses

The breeding projects on tall fescue and phalaris emphasize winter production and resistance to the root-pruning nematodes. Considerable variation within available germplasm in regard to these characteristics is evident and numerous selections have been made and are being further evaluated and recombined for additional selection.

Tall fescue is being selected for high Mg content especially under conditions of low soil O_2. The objective of this project is to reduce the grass tetany potential of tall fescue.

Nurseries of diverse orchardgrass germplasm have been established. Selection will be based upon persistence to extend the practical range of adaptation for this valuable forage species southward to include central Alabama.

Other forage legumes

Alfalfa is unquestionably the most valuable forage legume in the United States. However in the lower South, persistence of a productive stand beyond the first harvest year is unusual. Alfalfa nurseries are established for evaluation and selection primarily for persistence.

Recent introductions of birdsfoot trefoil from South America make available germplasm with the potential of yielding selections that are productive and persistent in Alabama. This material is being evaluated.

Arrowleaf clover has been remarkably free of damaging pests. Recently some arrowleaf clover stands have been severely damaged by an unknown malady locally called "red-leaf disease". Isolations strongly implicate a Fusarium sp. fungus as a primary causal organism. Spaced plants have been inoculated to verify this relationship and to possibly select for resistance.

The white clover breeding project emphasizes persistence. Selections within progeny of crosses among the parental clones of Regal for improved seed production are being made.

NEMATODES AND FORAGES

By C. S. Hoveland, R. L. Haaland, E. D. Donnelly, and R. Rodriguez-Kabana

Parasitic soil nematodes, known to cause serious losses in many row crops, have received relatively little attention from forage crop scientists. Serious work on nematodes must determine: (a) forage yield losses and the importance of nematodes on that forage crop species, (b) the particular nematode species attacking the plant, and (c) possibilities of lessening nematode losses by cultural methods, or nematicidal treatment, or breeding resistant cultivars. Research work in this area is tedious, time-consuming, expensive, and frustrating. Field experiments generally require 8 replications to deal with the extreme variability in soil nematode populations within an experimental area. Nematode populations are affected by soil temperature, moisture, availability of plant roots to feed upon, and the crop species grown previously. Screening techniques for developing nematode resistance or tolerance in forage species are often limited. Nematode resistance mechanisms and inheritance resistance mechanisms in most forage crops have not been elucidated. Effective nematode research on forage crops requires close cooperative work with a field-oriented nematologist. Finally, adequate numbers of technicians must be available to process and count nematodes in the large amount of soil and root samples generated in this type research.

Poor seedling establishment, low yields, and lack of persistence are often a result of nematodes attacking roots of forage crops. Nematodes in the southeastern USA have been shown to attack forage crop species such as orchardgrass and tall fescue (11), white clover (12), millet and sorghum-sudangrass (10) and perennial tropical grasses (2). Some results of forage nematode research at Auburn are summarized in this paper.

Sericea Lespedeza

Evidence that nematodes severely damage sericea lespedeza (Lespedeza cuneata) was obtained in 1955 by Donnelly (3). Several species of root-knot nematode were identified as causing damage and sericea lines differed in susceptibility (18). Forage yields were as much as 57 times greater for resistant entries than for the susceptible check (14). Resistance in two lines was caused by a single dominant gene while in another line a single dominant carried resistance but two genes were present in some individuals (1). Persistance and forage productivity of nematode-resistant lines have been superior (15), making prospects excellent for release of a sericea lespedeza cultivar adapted to sandy Coastal Plain soils where nematodes are a serious problem.

Vetch

'Warrior' vetch (Vicia sativa) developed at Auburn, is resistant to three of the five important root-knot nematode species (16). In contrast, hairy vetch (Vicia villosa) is susceptible to all five of the nematode species. Fewer

nematode larvae penetrated roots of the resistant Warrior variety and most of those that did enter failed to develop (17). V. leganua and V. angustifolia are susceptible to all five root-knot nematode species (13). Hybrids of V. sativa and V. cordata are resistant to three root-knot nematode species.

Cool Season Grasses

Productivity of cool season perennial grasses can be sharply reduced by parasitic soil nematodes. In trials at three locations in Alabama, establishment-year forage yields were doubled for phalaris (Phalaris aquatica) and tall fescue (Festuca arundinacea) and increased 3½ times for orchardgrass (Dactylis glomerata) at the first harvest with control of soil nematodes (6). In another experiment with tall fescue and phalaris, the establishment-year yields were increased 40 to 50% with nematode control (7). Second-year yield differences were generally much greater than the first year. Tall fescue yields were doubled with methyl bromide soil treatment and increased 40% with carbofuran above that of untreated soil. Phalaris yields were increased 4½ times with methyl bromide and over 2½ times with carbofuran. Results indicate a cumulative effect of nematodes, and possibly fungi, in depressing forage yields during the second year. Autumn and early winter forage harvests of tall fescue on methyl bromide-treated soil were two to four times that of untreated soil. Phalaris had little or no autumn growth on untreated soil, a result of root pruning by nematodes. This restricted grass roots to a shallow layer of soil, preventing utilization of water and nutrients at greater depths. Stand losses of phalaris occurred on untreated soil during a severe autumn drought.

The most important nematode species attacking the grasses were stunt (Tylenchorhynchus claytoni), lance (Hoplolaimus galeatus), and stubby root (Trichodorus christiei) (5, 7, 8, 9). Nematodes may interact with other organisms, particularly Fusarium, Pythium, and Rhizoctonia to cause pathological effects on phalaris (G. R. Smith. 1977. The use of greenhouse screening techniques to detect and characterize a nematode-disease complex of Phalaris aquatica L. M.S. thesis, Auburn Univ.).

Up to a 40% increase in autumn rye (Secale cereale) forage production has been obtained by soil application of carbofuran nematicide (9). Ryegrass (Lolium multiflorum) autumn forage yields have also been substantially increased by controlling soil nematodes (6).

Field application of nematicides and fungicides is not practical on cool season forages at this time. Several thousand tall fescue and phalaris seedlings have been screened for resistance to nematodes using techniques developed at Auburn (4, 5). Both resistant and susceptible plants have been selected for intercrossing to develop a resistant and a susceptible gene pool. Other screenings of cool season grasses have shown sufficient variability present to make progress towards nematode resistance.

Nematode-resistant grass cultivars will take several years to develop. In the meantime, seed treatment with nematicide may serve as an economical deterrent to the nemode problem, particularly on annual grass species. Greenhouse studies at Auburn have shown that rye, wheat, oat, and ryegrass seed treated with very small amounts of systemic nematicide will reduce nematode numbers in the rhizosphere (8). Oxamyl (Vydate) and carbofuran (Furadan) were relatively non-toxic to the seed while phenamiphos (Nemacure) was quite phytotoxic. Relative tolerances of the grass species to nematicide seed treatment were rye>wheat>ryegrass>oats.

SUMMARY

Nematodes are a major factor in reducing forage yields and stands of sericea lespedeza, vetch, tall fescue, orchardgrass, phalaris, ryegrass, rye, wheat, and oats in the southeastern USA. Legumes are attacked by root-knot nematodes while on grasses the major parasitic nematodes are stunt, stubby root, lance, and possibly dagger.

Breeding for host plant resistance to nematodes will be necessary to improve forage yields and extend the geographical range of forage species. Excellent progress has been made in achieving this objective on sericea and vetch. Seed treatment with nematicides on cool season annual grasses shows considerable promise in reducing nematode populations to permit better root development and more autumn and early winter forage production.

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Forage-Fed Beef in Alabama

By R. R. Harris

Cool season annuals such as oats, wheat, and rye interplanted with ryegrass and clovers have provided an excellent method of growing beef calves in Alabama. Under ideal weather conditions and cattle suited to this program slaughter beef can be produced directly from grazing and without benefit of a drylot feeding period.

This grazing program is adapted throughout Alabama and has been conducted effectively at 5 research stations, each with a different soil type.

Results from three tests will illustrate typical animal performance. In a 10-year test conducted in northern Alabama, the grazing season began October 21 and ended May 15th. During this 207-day period cattle actually grazed 147 days and were off grazing because of inclement weather or lack of forage for 60 days. The calves had initial weights of 441 pounds and gained an average of 282 lb/steer for the season (ADG - 1.37 lb.). The gain per acre was 536 lb. when pastures were stocked at an average rate of 1.9 calves per acre. However, the gain per acre and per steer included gain made from supplemental feed provided while off grazing. The ADG on grazing was 1.49 lb. and the gain from grazing only was 418 lb. per acre.

In a 4-year test, rye, oats and wheat were planted with ryegrass and clover. A comparison was made of animal response from grazing each of these combinations. Rate of gain was similar (1.64 to 1.75 lb. ADG) but gain per acre favored wheat slightly (570 vs 498, 499 lb). Stocking rates were very similar among these three small grains (1.94 strs/acre). Oats did winter-kill during two years of the study and cattle were removed from oat grazing longer during mid-Winter (76 days for oats; 66 for rye; and 59 for wheat).

In a 4-year test conducted in the Piedmont (central) area of Alabama, steer calved gained 2.0 lb. daily (394 lb/AC) from rye-ryegrass-clover grazing. Calves were larger than indicated for north Alabama tests (577 lb. vs 441, initial wts). In this central Alabama test, grazing began on Dec. 7th and ended June 5th (193 days). Calves were never removed from grazing during that period nor were they fed anything. Stocking was much lighter (1/AC) even though cattle were heavier individually.

Cattle from this central Alabama test were slaughtered directly from grazing without benefit of a finishing period. About 90% of their carcasses graded US Good and 10% were US Choice.

Feeding of about 1% of bodyweight as shelled corn on grazing increased gain per acre only very slightly (4%) but did increase stocking rate to 1.5 steers/acre (50%).

In a south central Alabama test, early-maturing steers grazed oats-ryegrass-clover during a 10-year study. The initial weights were 544 lbs. and they gained an average of 294 lb per steer from grazing (ADG = 1.58). In this area,

grazing began November 1; ended May 5th; cattle were fed for an average of 27 days while on grazing during this 186-day season. Under optimum conditions for 5 years of the total (10), cattle were slaughtered directly from pasture with essentially 50% of the carcasses grading US Good and the remainder US Choice. As noted above, the cattle were early-maturing type and were not removed from grazing during the Winter period.

SUMMARY

Good-Choice slaughter cattle can be produced directly from cool season annual pasture without feedlot finishing provided conditions are optimum. Stocker calves have typically gained above 1.6 lb. daily while on such grazing; producing about 400 lb. of gain per acre. If conditions are not optimum for direct slaughter, then cattle from these small grain - clover pastures are ideally suited for feedlot finishing.

RECYCLING ANIMAL WASTE ON FORAGES

By T. A. McCaskey

Land application of manure has been practiced for centuries, partly because there was no other place to put manure and partly because of the long recognized agronomic benefits resulting from manure. Manure has been shown to improve soil tilth, increase water-holding capacity, lessen wind and water erosion, improve aeration, and promote the growth of beneficial soil organisms. With the advent of increasing animal herds came the need to confine animals for more efficient management. For a herd of 100 dairy cows, each producing about 80 pounds of waste daily, the chore of managing the four tons of waste produced daily becomes a mounting problem. The fertilizer content of the waste amounts to about 16.5 pounds for total nitrogen, 5.2 pounds of P_2O_5, and 8.7 pounds of K_2O for the 100-cow herd per day (Table 1). Assuming that the waste is 20% solids the percentage of total nitrogen, P_2O_5, and K_2O expressed on a dry weight basis would be 1.03%, .32%, and .54%, respectively.

It is estimated that about two billion tons of animal waste are produced annually, enough to cover one square mile to a depth of 10 feet daily (5). During the turn of the century nearly all of the animal waste was applied to land to make use of its nutrients for plant growth. However, as herds increased in size waste was managed primarily to dispose of it rather than for soil amelioration and plant growth. Due to increased energy costs and the higher cost of mineral fertilizers the trend has been somewhat back to land application of waste.

Studies at Auburn University with animal waste management are varied and include work with treatment and disposal systems, effects on soil, crop yield and crop quality, pollution control, animal feeding, and health aspects associated with feeding waste to animals. Feeding studies began at Auburn about 1959, and studies with land applications began in the late 60's. Safety studies with waste feeding were begun in 1975 and presently are increasing in importance worldwide.

Land undoubtedly will remain the most logical place for ultimate disposal of manure. For this reason we must be concerned with rates of waste application that are consistent with good crop yields, yet do not interfere with crop quality nor pollute the soil or water. Some of the advantages of land disposal of manure compared to lagoons and other systems of managing waste are shown in Table 2.

Studies conducted at Auburn to determine the effect of various rates of dairy manure applied topically to Coastal bermudagrass showed that liquid waste applied at 20 tons/acre/year (T/A/yr.), expressed on a dry weight basis, by the irrigation or by the tank-wagon method did not appreciably affect the

TABLE 1.--Nutrient content of animal wastes[a]

	Total N	P_2O_5	K_2O
	- - - - Pounds/100 animals/day - - - - -		
Swine	4.3	3.7	1.6
Poultry	2.9	2.9	1.0
Beef	16.0	16.0	4.7
Dairy	16.5	5.2	8.7

a/ From: Townshend, A. R. et al. 1969. Animal Waste Management, Cornell University, January 13-15, p. 131.

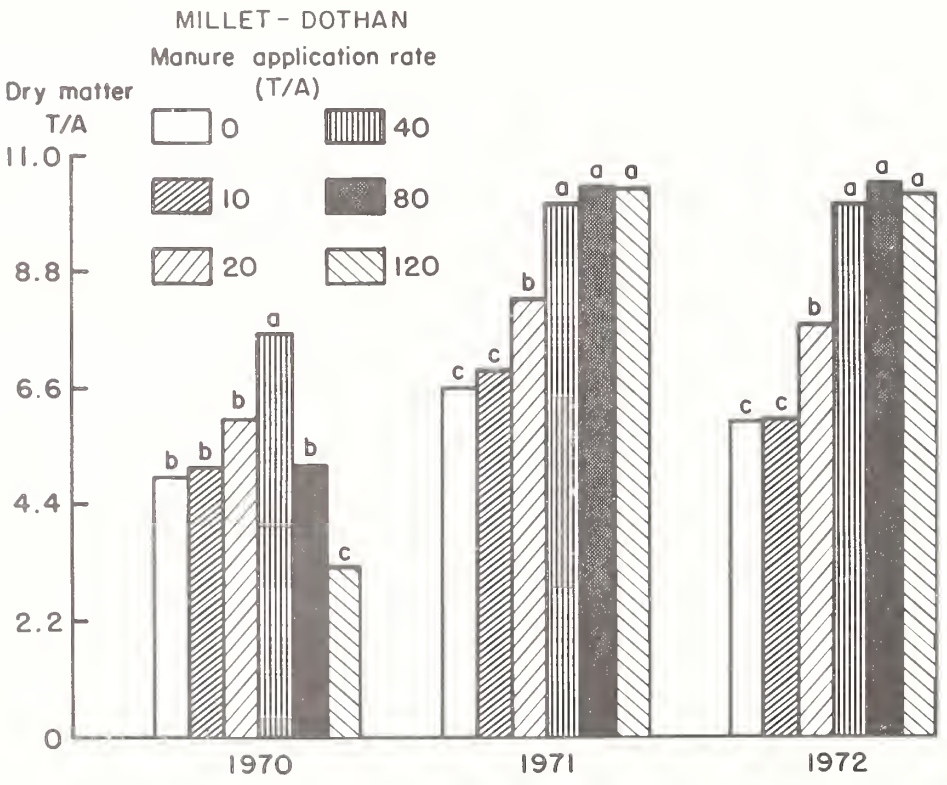

FIGURE 1.--Effect of manure application rate on Dothan soil. Yields with the same letter are not significantly different at the 5% level within years as determined by the Duncan Multiple Range Test. From: Lund et al. 1975. J. Env. Qual. 4:358.

quality of runoff water from the land (4). Pollution of ground and surface waters from land application of animal wastes is still a potential problem; however, the problem is much less severe than was originally thought.

Millet and Rye Grown on Soil Incorporated Manure

The effect of rate of land application of dairy manure on forage yield has been studied at Auburn by Agricultural Research Service scientists in cooperation with the Department of Agronomy (1,2,3).

A three-year study was conducted to determine the effects of various rates of manure application on forage yield and quality of rye and millet double-cropped on two types of soils (2). Fresh dairy manure was incorporated into plots at the rate of 10, 20, 40, 80, 120 T/A dry weight basis before planting each year. The check plot (no manure) received 100 pounds/A each of N, P and K, and except for one of the three years of study, an additional 82 pounds/A each of N, and K was surface applied after each cutting. Two soil types were used in the study, one a Dothan loamy sand and the other a Lucedale fine sandy loam. The average analysis of manure N, P, and K on the soils following application is shown in Table 3. Millet was planted on all plots in the spring following fertilization. The millet was cut when it reached 50 to 64 inches height. Rye was planted in the fall and cut early the following spring.

Millet yielded more forage on Dothan soil at high manure application rates than at lower rates, except in 1970 when emergence and early growth were reduced at the high rates, probably due to ammonia toxicity (Fig. 1). One week after manure application surface soil pH increased to 8.7. The high application rates in 1971 and 1972 did not cause emergence failure and the pH of the soil did not rise substantially. Residue from the previous year's application caused a buffering action that prevented a large increase in pH. The 40 T/A manure rate produced the highest yield of millet in 1970. During the next two years the highest millet yields occurred with the three highest manure application rates. Yields of millet on the Lucedale soil followed a pattern similar to that on the Dothan soil (data not shown).

Yields of rye on Dothan soil in 1970 were not increased by manure application rates higher than 40 T/A. During the next two years yields were not increased significantly by manure rates higher than 20 T/A. On Lucedale soil (data not shown) the two highest rates of manure yielded the most rye forage for all three years.

Nitrate content was higher for millet and rye grown on Dothan soil than on Lucedale soil (Fig. 2). Both millet and rye had nitrate N contents above .4% when 80 and 120 T/A of manure were applied. At the 40 T/A rate millet produced on the Dothan soil had nitrate N at about the .4% level considered toxic to ruminant animals. All forages were considered tetany prone with K/(Ca+Mg) ratios above 2.2 except millet produced with the lowest manure application rate (10 T/A) and the check plot (Fig. 3).

TABLE 2.--Advantages of manure disposal on land

1. Economical.
2. Efficient aerobic decomposition of manure by microbes in soil.
3. If manure is plowed down, higher rates can be applied and fly, odor, and runoff pollution will be practically eliminated.
4. Improved crop yield from nutrients and organic matter.

TABLE 3.--Average analysis of dairy cattle manure*

	N	P	K
	- - - - - - - - - - Percent - - - - - - - - - -		
Dothan loamy sand	1.98(.43-3.12)[a]	.67(.37-.83)	1.14(.45-1.74)
Lucedale sandy loam	1.91(.77-2.64)	.49(.37-.84)	1.25(.54-1.56)

a/ Values in parentheses are ranges.
* From: Lund et al., J. Environ. Qual. 4:195.

TABLE 4.--Effect on manure fertilization on ratios of K/(ca + mg) in Coastal bermudagrass forage*

Treatment	Dothan loamy sand			Lucedale sandy loam		
	1971	1972	1973	1971	1972	1973
Check	1.60	1.30	1.42	1.56	1.40	2.16
Dairy manure[a]	1.50	1.09	1.49	1.52	1.20	1.99

a/ Average of all manure treatments.
* From: Lund et al., 1975. J. Environ. Qual. 4:195.

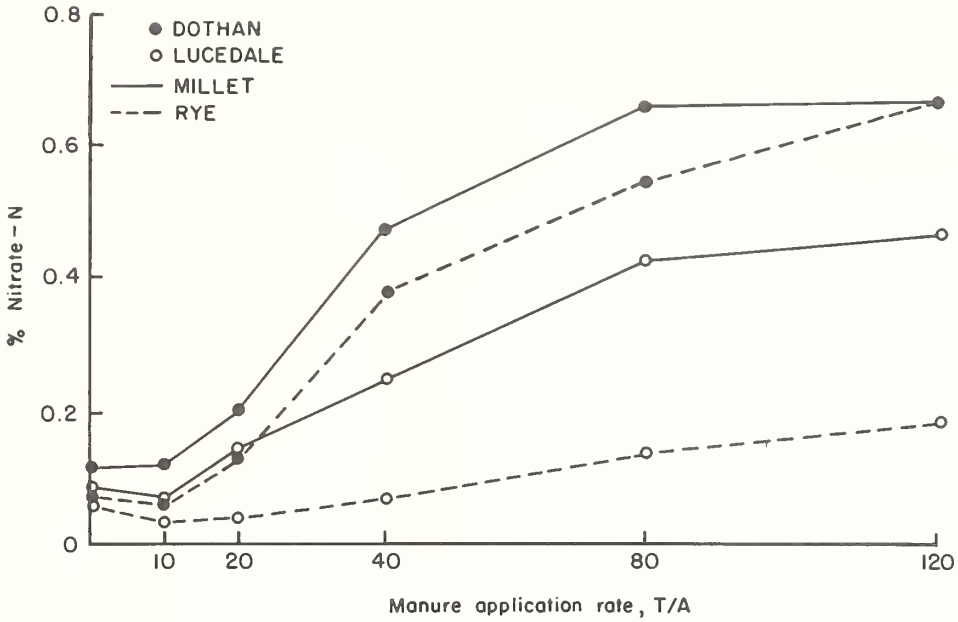

FIGURE 2.--Effect of annual manure application rate on 3-year average nitrate level in forage. From: Lund et al. 1975. J. Env. Qual. 4:358.

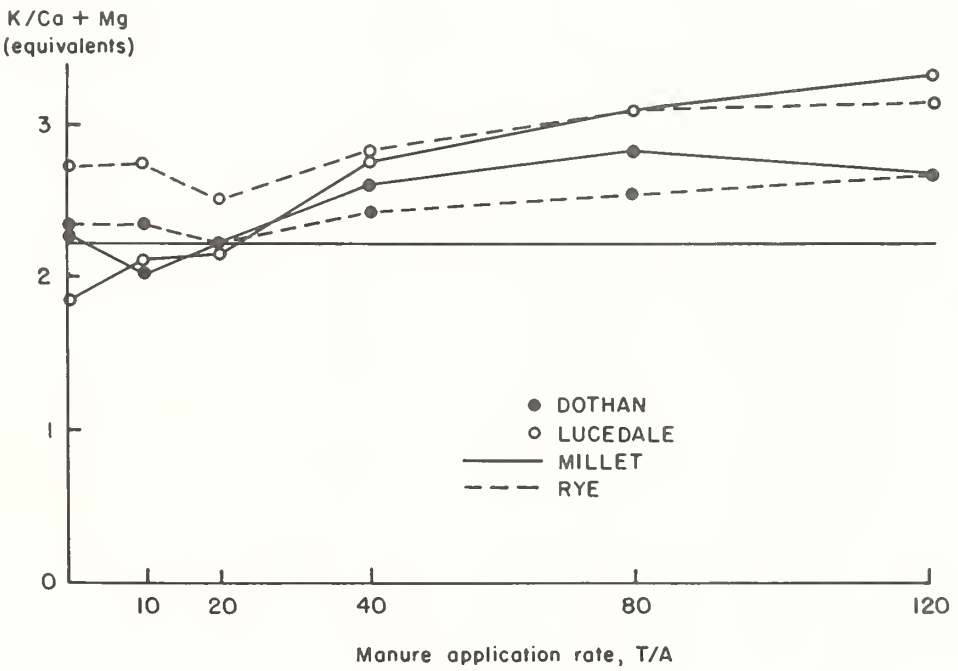

FIGURE 3.--Effect of annual manure application rate on 3-year average equivalent ratio of K/(Ca + Mg). From: Lund et al. 1975. J. Env. Qual. 4:358.

Coastal Bermudagrass Grown on Soil Surface Applied Manure

A three-year study was conducted to determine the rate of solid and liquid dairy manure that may be surface applied to established stands of Coastal bermudagrass on Dothan and Lucedale soils (3). Treatments consisted of a mineral fertilizer check and five manure treatment rates: solid manure at 20 and 40 T/A/yr., and liquid manure at 20, 40, and 60 T/A/yr. Manure application rates were divided into six applications at approximately 2-month intervals, and all rates are expressed on the dry weight basis. Each week during the growing season at least 1 inch of irrigation was applied to the plots or 1 inch of rainfall occurred. The check plot received four applications of mineral fertilizer, totaling 470, 225, and 470 pounds/A/yr. of N, P, and K, respectively. These rates were high, but the rate of N was comparable to the amount of N estimated to be available per year in the lowest rate (20 T/A) of manure. Coastal forage was clipped on the plots when it reached 14 to 20 inches height.

During the first year of the study the yield of Coastal bermudagrass on Dothan soil was less on plots receiving solid manure than on those receiving an equivalent amount of dry matter from liquid manure (Fig. 4). The nutrients in the liquid manure moved into the soil better and were available for plant growth. The 20 T/A rate of liquid manure produced less bermudagrass than the check plot indicating that not all of the nutrients were available for plant growth although the 20 T/A rate was similar in nitrogen fertilization compared to the check plot. The 40 T/A rate of liquid manure gave the same yield of bermudagrass as the check plot. In 1972 all treatments resulted in higher yields and the solid manure treatments produced as much forage as the liquid manure treatments at the same application rate (Fig. 4). Treatment effects on the Lucedale soil were similar to those for the Dothan soil (data not shown).

Nitrate N in the Coastal forage increased with the rate of manure application (Fig. 5). During the first year of the study the difference in nitrate N was ninefold (.015 to .141%) between the lowest (20 T/A) and the highest (60 T/A) manure treatments. Differences were also evident during the next two years of the study. The uptake of nitrate N was greater for Coastal grown on liquid manured plots than solid manured plots receiving an equivalent rate of application on the dry weight basis. None of the manure rates nor the check plot resulted in forage nitrate N levels greater than the .4% level considered toxic to ruminants. Grass tetany which may be associated with manured forages was not evident at any of the manure rates studied. The ratio of K/(Ca+Mg) in the forages were below the tetanic level of 2.2 except the forage on the Lucedale soil check plot during the third year of study (Table 4).

CONCLUSIONS

Millet and Rye Grown on Soil Incorporated Manure

Rates of 10 and 20 tons/acre of dairy cattle manure incorporated into soil produced millet and rye forage of good quality. When rates of application exceeded 40 T/A forage was high in nitrate and had K/(Ca+Mg) ratios that could be detrimental to animal health. When high rates of manure were used, the Dothan soil produced forage higher in nitrate than did the Lucedale soil. The forage produced with high rates of manure on Lucedale soil had higher

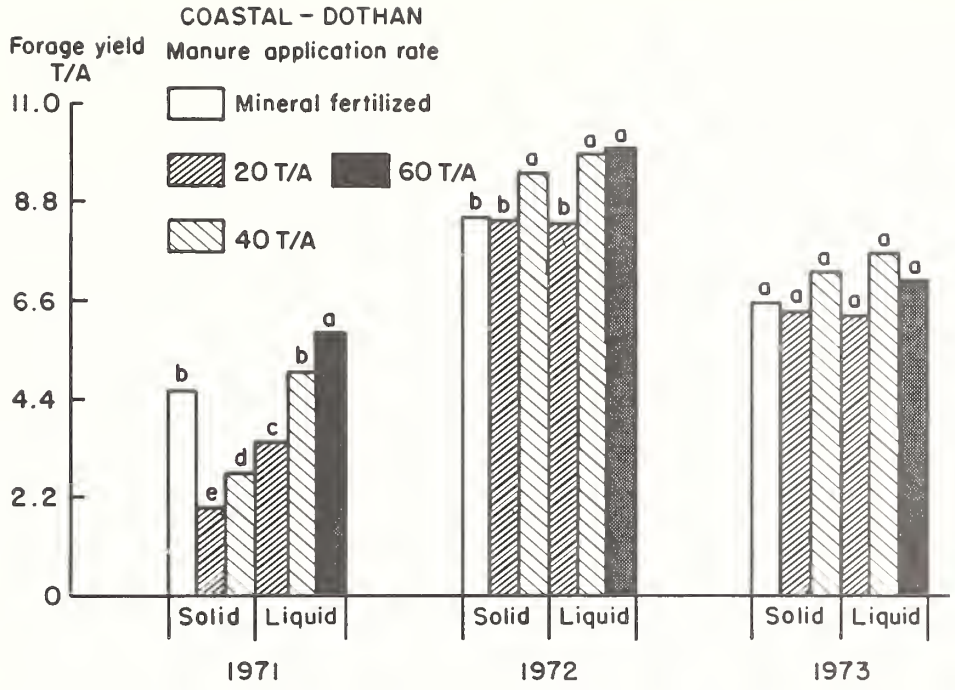

FIGURE 4.--Effect of dairy cattle manure on yield of Coastal bermudagrass on Dothan soil. Bars with the same letter within the same year are not statistically different at the 5% level. From: Lund et al. 1975. J. Env. Qual. 4:195.

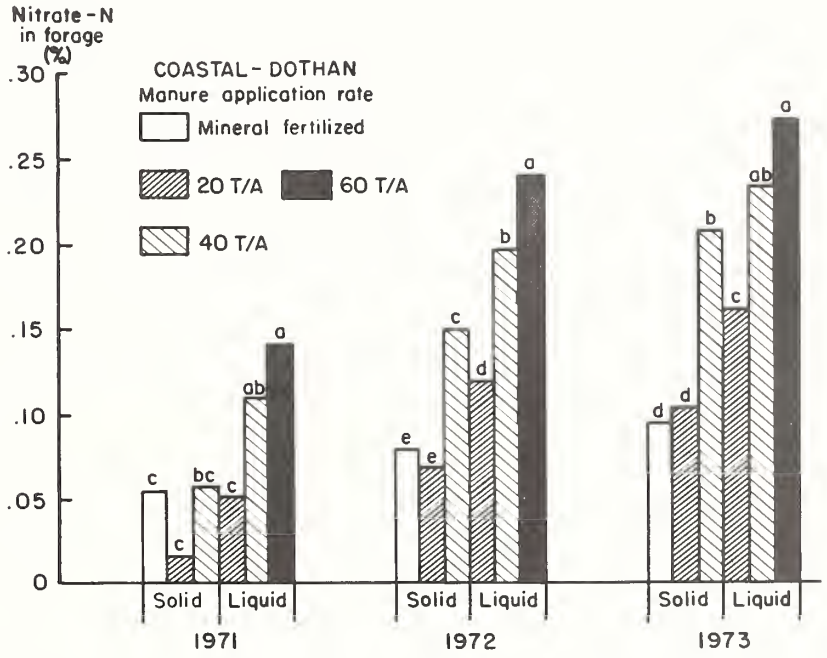

FIGURE 5.--Nitrate content of Coastal bermudagrass grown on manure-treated plots on Dothan soil. Bars with the same letter within the same year are not statistically different at the 5% level. From: Lund et al. 1975. J. Env. Qual. 4:195.

K/(Ca+Mg) ratios than did that of Dothan soil with equal rates of manure application.

Coastal Bermudagrass Grown on Soil Surface Applied Manure

Split applications of dairy cattle manure totaling 20 and 40 T/A/yr. did not provide sufficient nitrogen for maximum production of Coastal bermudagrass forage the first year. Liquid manure was more effective than solid manure at an equivalent rate for forage production the first year. Accumulations from continuing applications at the 20 T/A/yr. rate produced excellent yields of high quality forage the second year on the loamy sand and the third year on the sandy loam. Rates of 20 T/A/yr, could be used for 3 years without impairing forage quality. Three years' application of manure at rates of 40 and 60 T/A/yr. had become detrimental to stand and weeds began to encroach upon the Coastal bermudagrass. There was also an indication that applications of 60 T/A/yr. over a period of years could produce Coastal bermudagrass forage with levels of nitrate that exceed tolerance levels for ruminant animals.

These studies conducted by Auburn researchers indicate that 20/T/A/yr. of dairy cow waste (dry basis) can be used in fertilization programs for millet, rye, and Coastal bermudagrass without impairing crop yield or quality. Higher manure application rates than 20 T/A/yr. can be used on Coastal bermudagrass without causing a tetanic condition or hazardous levels of nitrate in the forage. Millet accumulates nitrate and although 20 T/A/yr. of manure can be used the manure application rate should be reduced to 10 T/A/yr. after the second or third year of production.

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GRASS ROOTS AS A TOOL FOR PENETRATING SOIL HARDPANS AND INCREASING CROP YIELDS

By Charles B. Elkins, Ronald L. Haaland, and Carl S. Hoveland

Most of the agricultural soils of the Southeast are coarse-textured. These sandy soils have low water-holding capacities and are easily compacted. Often the roots of common crops such as cotton, corn, and soybeans, are restricted to the plow layer by traffic pans. As a result of shallow rooting in these low-water-storage soils, plants are often subjected to water stress in 3 to 6 days after the soil is thoroughly wet by rainfall.

For example, a typical Southeastern soil will store 1 inch of available water per foot of soil. If rooting is 6 inches deep and the crop is using water at a rate of 0.17 inch per day, then, following rainfall that wets the 6-inch rooting zone, the crop would have a 3-day supply of water (Table 1). After 3 days the crop would be under water stress until the next rainfall or irrigation. The table shows how length of time that the plants will be free from water stress increases as rooting depth increases. Actually, the benefits from deep rooting may often be greater than shown in the table because the water-holding capacity of many soils increases with depth.

Ward et al. (5) have used long-term weather records, soil-water data, and water-use data to predict drought occurrence. From their work (Table 2), we determined that for the average Coastal Plain soil in east-central Alabama a crop with a rooting depth of 12 inches will, in 5 out of 10 years, experience 60 drought days during May through August. If rooting were 5 ft deep, the crop would experience only 11 drought days.

Subsoiling usually comes to mind when one thinks of ways to break through traffic pans to promote deep rooting. However, crop response to subsoiling has often been variable (3), and any form of deep tillage increases energy requirements. A highly desirable alternative to subsoiling would be plant roots with the ability to penetrate dense soil. Ideally, we would like to have this characteristic in each plant that we grow. This seems unlikely in the near future, but a useful second choice might be cropping sequences in which one plant in the sequence has roots that can penetrate dense soil. The penetrating roots would hopefully modify the soil hardpan and make possible deep rooting by following crops.

'Pensacola' Bahiagrass (*Paspalum notatum* Flügge)

One plant that shows much promise for such use is Pensacola bahiagrass. Observations in the Auburn rhizotron in glass-front boxes and in the field have shown that bahiagrass roots will penetrate artificial and naturally-occurring traffic pans that stop most crop roots. Doss et al. (1) found more bahia roots than common and Coastal bermudagrass (*Cynodon dactylon* (L.) Pers.), sericea lespedeza (*L. cuneata* (Dumont) Don), and dallisgrass (*Paspalum dilitatum* Poir.) roots in the 6- to 36-inch depths of a Greenville fine sandy loam soil. Peterson, et al. (4) found morphological features of bahia roots that may explain their ability to penetrate dense soil. A predominant feature is a

TABLE 1.--Days without plant water stress following rainfall for different rooting depths. (Available water = 1 inch/foot of soil; Evapotranspiration = 0.17 inch/day*)

Rooting depth	Days without water stress following rainfall
inches	
6	3.0
9	4.5
12	6.0
24	12.0
36	18.0
48	24.0
60	30.0

* Average ET for south Alabama, May through August (from Ward et al. 1959. Drought in Alabama)

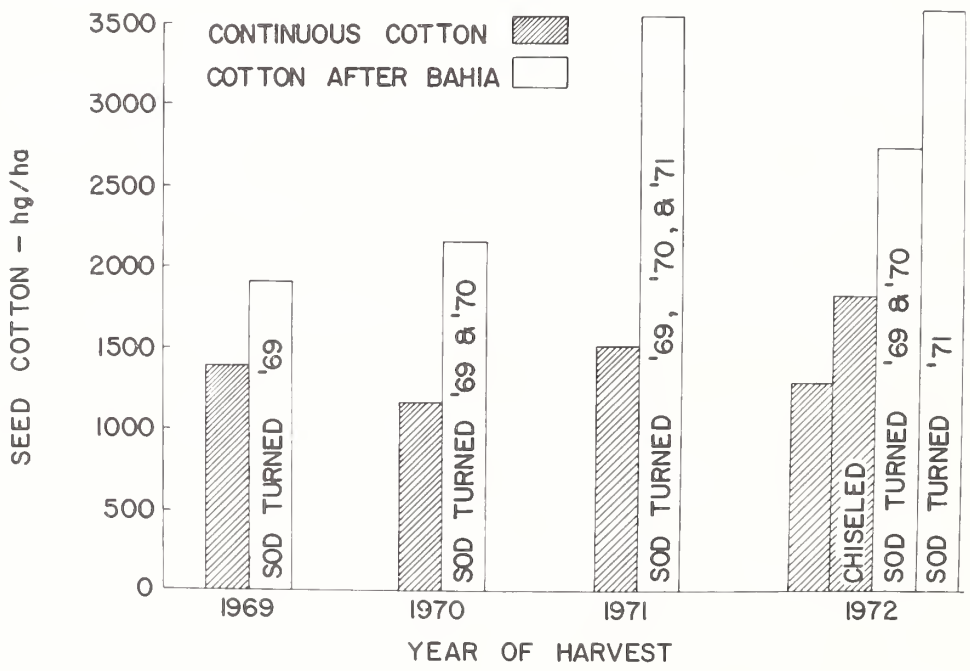

FIGURE 1.--The effect of Pensacola bahiagrass sod and deep tillage on cotton yield, Tallassee, Alabama.

fibrous sheath beneath the epidermis that gives the root rigidity.

In an experiment on a Cahaba loamy sand soil at Tallassee, Alabama (2), average cotton yields over 4 years were increased from about 1 bale per acre where cotton was grown continuously to about 2 bales per acre when cotton was grown after bahiagrass (Fig. 1). Figure 2 shows that on continuous cotton plots, roots were restricted to the 9-inch (23 cm) plow layer, but grew to more than 24 inches (60 cm) when cotton followed bahiagrass. Numerous cotton roots were 6 ft deep on the bahiagrass plots.

Soil water measurements showed that more subsoil water was removed by cotton following bahiagrass than by continuous cotton. Chiseling the soil 14 inches deep increased deep rooting and yield, but not as much as growing cotton after bahiagrass (deep tillage treatment - Figs. 1 and 2).

The only measurable chemical or physical change in the soil that could explain the deep rooting and better plant performance of cotton following bahiagrass was the change in porosity of the traffic pan (Fig. 3). Bahiagrass roots caused only a slight increase in small pores but an eightfold increase in pores greater than 1.0 mm in diameter. The primary roots of mature Pensacola bahiagrass are 1 to 2 mm in diameter. Bahia roots have a strong positive geotropism and, thus, form relatively straight vertical pores through the soil profile--sometimes more than 6 ft deep. These pores through a traffic pan continuing into subsoil should be very effective in increasing saturated water movement and, thus, improve drainage, aeration, and water percolation in the compacted soil zone. They also provide channels through which roots of other plants can grow.

Tall Fescue (*Festuca arundinacea* Schreb.)

Bahiagrass is best adapted to the mild climate of the southern Coastal area but plants with the ability to penetrate dense soil are needed for colder climates. Because of its widespread adaptability and use, tall fescue is an obvious plant to look to for this characteristic. Since preliminary evaluation indicated that tall fescue was heterozygous for root diameter, we screened 216 genotypes from four tall fescue lines for root size distribution. Two genotypes, Auburn 81 with a preponderance of small roots, and Auburn 7 with larger roots (Fig. 4), were grown over compacted soil for 4 months. Roots of genotype 81 did not penetrate the compacted soil, but several of the 3.4- to 3.6-mm diameter roots of genotype 7 penetrated the compacted soil. The roots that penetrated increased in diameter by about 75% when they came in contact with the compacted soil and maintained this larger diameter until leaving the compacted soil, whereupon they returned to their original diameter. Tall fescue roots do not have a fibrous sheath as do bahiagrass roots. Bahiagrass roots do not increase in diameter when growing in dense soil, so different mechanisms for penetrating dense soil seem to operate in the two species.

Conclusions and Plans for Additional Research

We can conclude that at least on some soils, plants such as bahiagrass can be used to modify the porosity of traffic pans and improve performance of following crops. The bahiagrass cropping system is being tested on additional soil types with corn, peanuts, and soybeans. Tall fescue genotype 7 is being vegetatively increased for field testing on a traffic pan soil. Our objectives for ongoing and future research are to more fully understand the different mechanisms that roots use to penetrate dense soil, and to identify root

TABLE 2.--Probability of minimum number of drought days in east-central Alabama for soils with various water storage capacities.

Month	Prob.	Area E			
		Base amounts			
		1"	2"	3"	5"
		Minimum drought days			
May	1/10	25	21	19	7
	2/10	23	18	14	4
	3/10	21	16	11	1
	5/10	17	12	6	0
June	1/10	25	25	24	21
	2/10	23	22	20	16
	3/10	20	19	18	12
	5/10	17	14	13	6
July	1/10	22	20	20	18
	2/10	18	17	16	14
	3/10	16	13	13	11
	5/10	12	9	7	5
Aug.	1/10	22	18	17	16
	2/10	19	14	12	10
	3/10	17	12	8	6
	5/10	14	8	3	0

(From Ward, Henry S. et al. 1959. Agricultural drought in Alabama. Ala. Poly. Inst. Ag. Exp. Sta. Bull. 316)

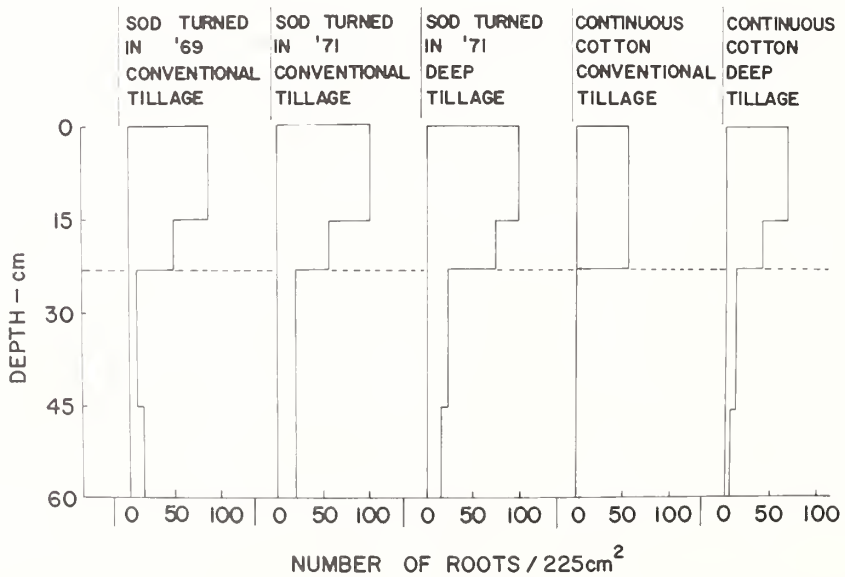

FIGURE 2.--The effect of Pensacola bahiagrass sod and deep tillage on cotton root penetration of a traffic pan in a Cahaba loamy sand soil, Tallassee, Alabama. (Dotted line shows depth to traffic pan.)

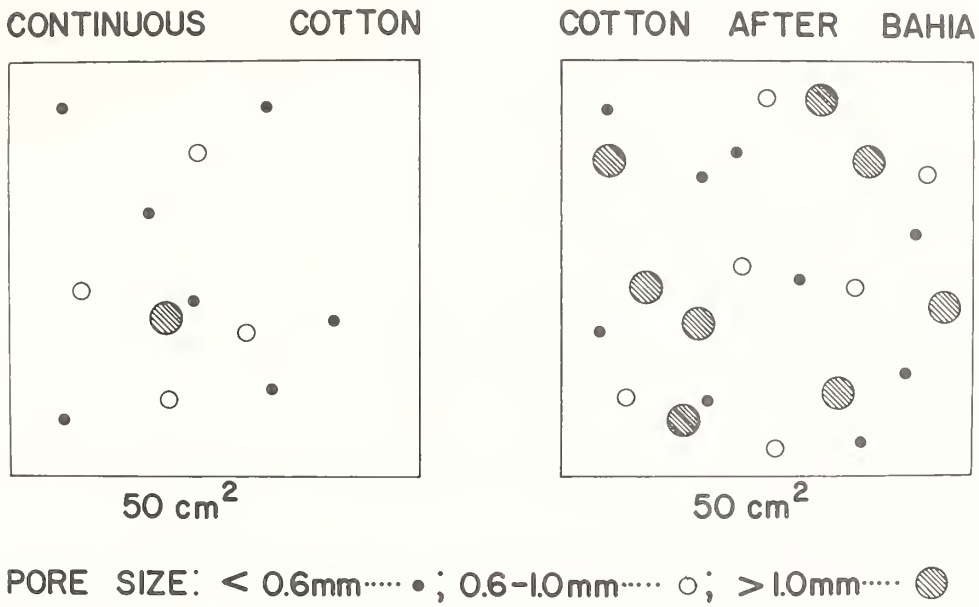

FIGURE 3.--Distribution of macropores in the traffic pan of a Cahaba loamy sand soil cropped to continuous cotton and cotton after bahiagrass.

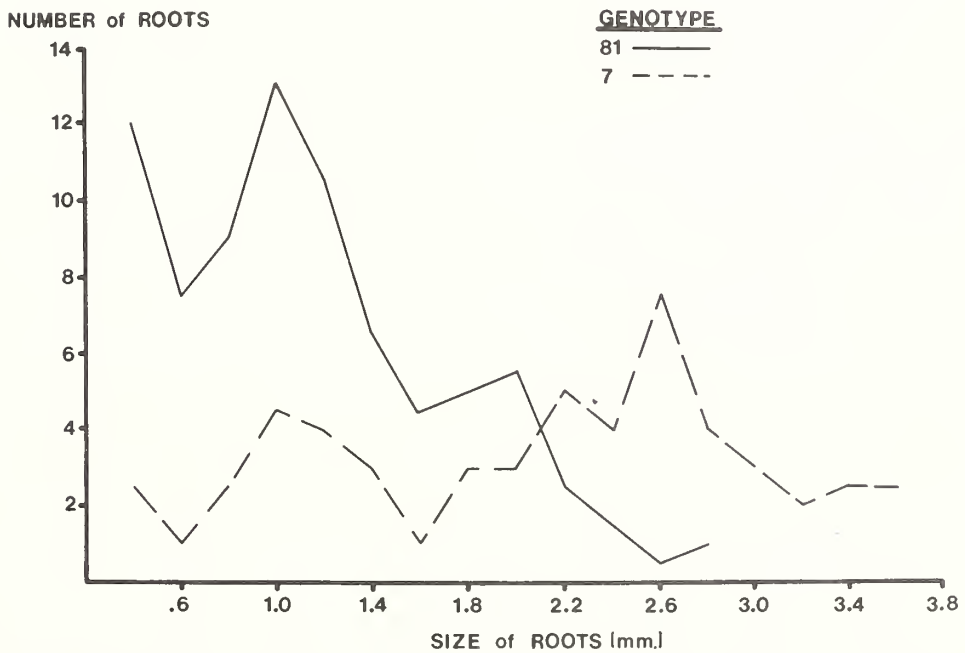

FIGURE 4.--Root size distribution of two tall fescue genotypes.

characteristics associated with these mechanisms. Hopefully, these characteristics can be incorporated into useful cultivars.

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ANTI-QUALITY RESEARCH ON FORAGES

By R.L. Haaland, E.D. Donnelly, C.B. Elkins and C.S. Hoveland

Sericea

Sericea lespedeza (Lespedeza cuneata (Dumont) G. Don), is a perennial warm-season legume well adapted to the southeastern United States. However, it has been found to have low palatability and nutritive value. In 1950, a breeding program was initiated at Auburn to improve the quality of the species.

Both stem size and tannin content were shown to contribute to the poor quality of sericea (2, 3). By evaluating large populations for stem size and combining the fine stemmed material, an improved fine stemmed variety 'Serala' was developed (4). Although Serala is a high tannin variety, beef cattle produced 88% as much gains on it as on Bahiagrass that received 168 kg of Nitrogen per hectare (9).

Low-tannin sericea plants were found to have higher dry matter and crude protein digestibility than normal high-tannin plants (5, 6). Low-tannin was introduced into Auburn germplasm from a Beltsville selection, 23-864. Cattle grazed on a low-tannin sericea line performed better than on a high-tannin line (9). Performance on the low-tannin line equalled that on bahiagrass that had received 168 kilograms of nitrogen per hectare annually.

Although low-tannin sericea shows much improved forage quality, it is not without problems. Tannins have fungicidal properties. Early low-tannin lines were found to be susceptible to Rhizoctonia sp. during hot humid weather. However, additional breeding efforts have produced disease resistant low-tannin lines (7). If resistance of this new material is adequate, it will make an expanded contribution to forage production in the Southeast.

Phalaris

Phalaris (Phalaris aquatica L.), a cool-season perennial forage grass, has the potential for excellent winter forage production in the Southeast. Phalaris has been grown in Australia for many years as a winter forage and animal metabolic disorders (staggers and/or death) have periodically developed. These problems have generally been attributed to alkaloids found in phalaris. Phalaris genotypes investigated at Auburn have been relatively low in alkaloids, usually less than 0.3 percent of dry weight (1). A grazing trial on phalaris at the Black Belt Substation in Alabama resulted in steer gains of about 1.5 pounds per day and no metabolic disorders were evident.

Tall Fescue

Several million acres of tall fescue are grown for forage in the Southeast. At times, ruminants grazing tall fescue will show symptoms of grass tetany. Grass tetany is caused by low blood serum Mg. Forages with low Mg content contribute to grass tetany. The tetany problem usually occurs during cool wet periods. Research at Auburn (8) has shown that low soil O_2 will

depress Mg uptake in tall fescue. Forage grown on water logged soils commonly found in late winter or early spring may be more conducive to grass tetany because of the low soil O_2. Initial screening of tall fescue germplasm has shown that there is variation for the ability to accumulate Mg at low O_2 levels (8). If this trait proves to be heritable new grass tetany resistant tall fescue varieties may be developed.

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SYSTEMS FOR BACKGROUNDING CATTLE

By H. W. Essig

The Southeast continues to be a leader in beef cattle production. The bulk of this beef production has been largely centered around the cow-calf operation, in which the calf is weaned and sold at weaning time. With advancing technology, expansion of farm size and lowered demand for young cattle, many producers are retaining ownership of their weaned calves and attempting to increase the weight to approximately 700 lb. This period of time from weaning to growing the animal to an appropriate size for placing in a finishing program is often referred to as "backgrounding." My talk will be centered primarily around systems for growing cattle from weaning to a weight sufficiently large enough to allow the animal to be placed on a feeding system.

There are many confusing terms related to backgrounding of cattle. The terms "preconditioning," "conditioning," "backgrounding," and "stocker programs" are quite often interrelated and are oftentimes used synonymously. I would like to offer some definitions for these terms. "Preconditioning" is often defined as preparing the calf to better withstand the stress of leaving its mother and learning to eat new kinds of feed. Generally, preconditioning is performed on the animal prior to weaning and is done by the cow-calf producer before the animal is sold. Preconditioning involves such management practices as identification, castration, dehorning, weaning, immunization, nutritional adjustments, external and internal parasite controls, as well as allowing the animal to become accustomed to handling. In essence, preconditioning is nothing more than good management practices. "Conditioning" may be defined as preparing the weaned animal to withstand stress associated with readying for the feedlot. The conditioning practices would be nothing more than applying the management practices that were not administered during a preconditioning phase. "Backgrounding" is defined as a practice used by some feedlot operators to get calves accustomed to their new environment before they are placed in the feedlot. This definition is the one that was originally applied to the practice of backgrounding. However, this definition has now changed to a great extent to cover the period of time between weaning and the time the animal is placed in the feedlot. This broad definition also would be synonymous with stocker programs in which young cattle are grown from weaning until entering the feedlot or breeding herds. These cattle are usually referred to as "stockers." In the Southeast, the stocker programs are generally synonymous with backgrounding programs.

The Southeast is ideal for stocker or backgrounding programs since the climate is conducive to good year-round forage production and utilization systems. With the proper combination of warm and cool season legumes and grasses, the growing season can be stretched to nearly 365 days per year. This is particularly true for areas near the Gulf Coast. However, as operations are located further north from the coastal area, the growing season decreases to less than the 365 days per year. The Southeast has an abundance of rainfall, and a large portion of this rainfall is spread throughout the year, allowing

for forage production from either warm season or cool season forages. Capital for livestock operations has been somewhat of a problem in past years; however, there appears to be a greater availability of capital for livestock production in the Southeast in recent years. This is particularly true with the advent of the backgrounding programs, in which the cool season annuals supply a bulk of the forage for the backgrounding programs. Fertilizer has been available and in the past, has been a relatively economical source of nutrients for plants and has allowed for economical production of forages. The Southeast has soils that are adaptable to forage-livestock systems and has topography that allows for grazing during a large portion of the year. There have been marketing channels developed in the Southeast. These allow the producer to retain ownership of animals through the backgrounding phase and then market these animals or retain ownership of the animals and place them in feedlots. These alternatives provide the producer the opportunity to maintain ownership through a finishing program or to dispose of the animal upon completion of a backgrounding program. One final point that makes the Southeast an ideal stocker-backgrounding area is the native ability for managing the complex microenvironment-soil-plant-animal farming business. With all of these advantages, the Southeast is in the driver's seat as far as the stocker or backgrounding programs are concerned. There is no other area in the country that has the advantages for a backgrounding program that occur in the Southeast.

Livestock-forage systems can be divided into different schemes (fig. 1). In this breakdown, the forage systems are divided into grasses and legumes, with the grasses and legumes further divided into annuals and perennials. The annuals and perennials can further be divided into warm season or cool season annuals or perennials for which some examples have been given. Warm season annual grasses would include such things as corn, sorghum, or some of the sorghum-sudan hybrid crosses. Generally corn or sorghum would either be produced for silage, harvested for grains, or both. The sorghum-sudan cross materials could be either grazed or harvested as a stored forage.

The cool season annuals would be such things as the cereal grains or ryegrass, or a combination of the various cereal grains and ryegrass. This is often referred to in the Southeast as "winter grazing," and there are programs which use wheat, oats, rye, ryegrass, triticale, singularly or in combination. These programs may also be combined with clovers. There is a host of perennial warm-season grasses, of which the bermudagrasses are probably the most prevalent. Bahiagrass is also abundant in the extreme southern portion of the Southeast, and the bermudagrasses would occur throughout the southeastern United States. The cool season perennial grasses such as fescue occur in the upper Southeast and orchard grass occurs in the extreme northern portion of the Southeast. The systems division for legumes also contains annuals and perennials. A good example of a summer annual legume would be lespedeza. There is a variety of annual winter or cool season clovers such as as the arrowleafs, crimson, and subterranean clover. These annual clovers are used in combinations with the cool season annual grasses and afford very profitable systems of livestock production. The perennial legumes are used generally in combination with some of the perennial grasses. Perennial legumes that are used are the ladino clovers and some red clover. Alfalfa may be used, but generally alfalfa is used more for a hay crop than it is for a grazing crop in the Southeast. This outline for forage systems involving grasses and legumes for annual or perennial cool season or warm season production is by no means a complete list. All of these forages should be considered for use in forage systems in the Southeast.

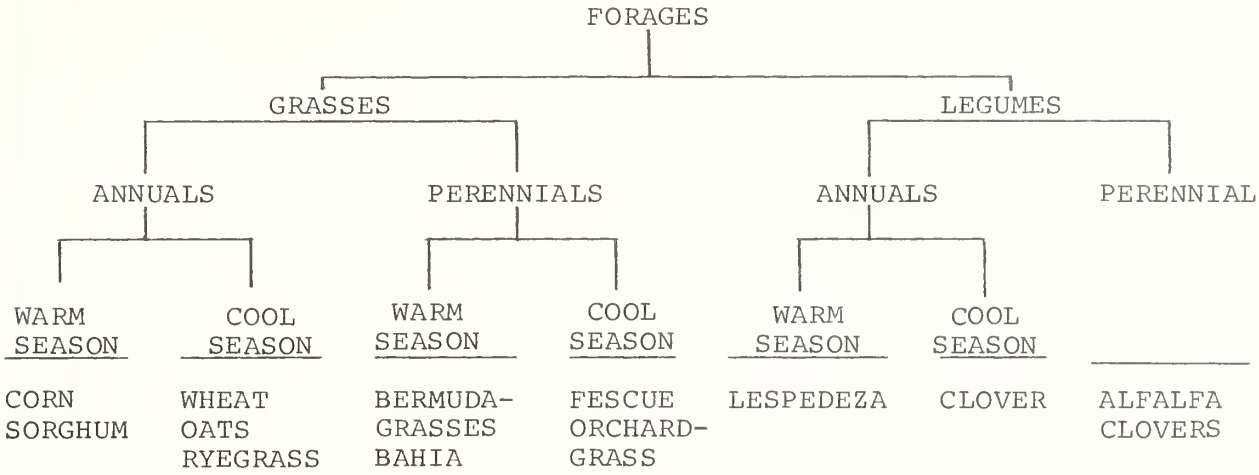

FIGURE 1.--Plant components of livestock-forage systems.

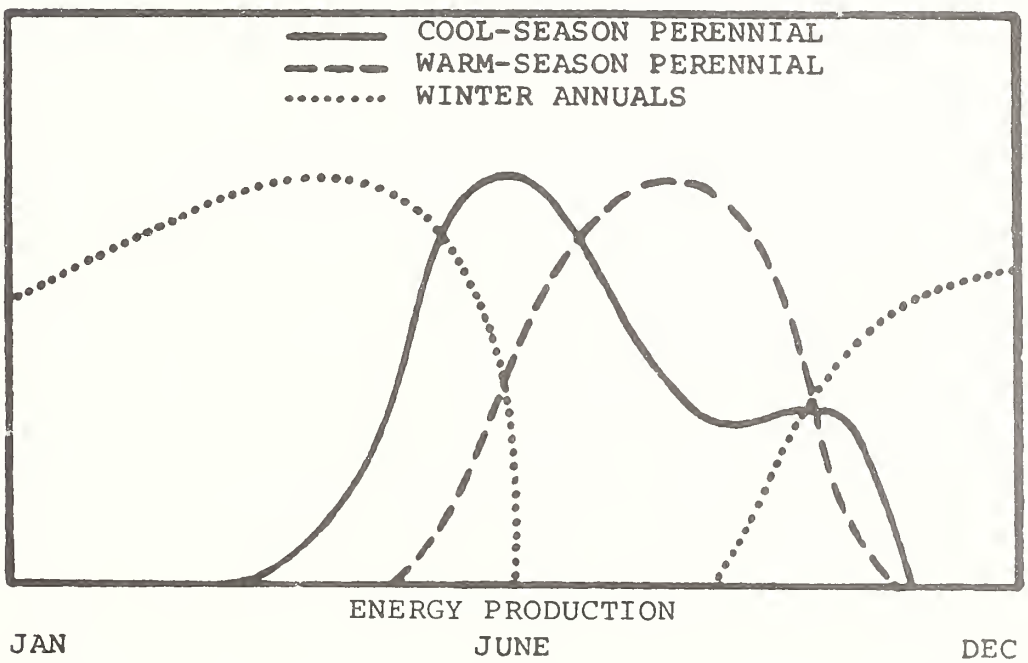

FIGURE 2.--Generalized pasture availability curve.

In developing backgrounding systems, the objective is to use as many combinations of cool season perennials, warm season perennials, and the winter annuals as possible, in order to produce as large a quantity of high-quality forage as possible. A generalized pasture availability curve has been constructed (fig. 2). This diagram indicates the relative energy production for the winter annuals, the cool season perennials and the warm season perennials. By looking at this generalized production availability curve for different forages it is obvious that forage utilization systems need to be constructed that will allow for maximum energy usage during the period of time from early spring through July. A generalized scheme for an energy requirement of a growing animal shows the energy requirement is on a continuing or rising basis. This energy requirement generally is a function of body weight, so that as the animal increases in weight, the energy requirement for maintenance is increased. When this maintenance energy requirement is combined with the energy requirement for gain, the total energy requirement increases in a linear manner (fig. 3).

If the energy requirement of the growing animal is imposed on the energy production for the different forage systems, it is apparent that as the animal increases in weight or size, the energy requirement increases and that there is the possibility that late in the season the energy requirement of the animal may be greater than the energy production potential of the forage system. This indicates that in a forage-livestock production system, it is imperative to utilize the forage that is produced in the early portion of the season. The area in the forage production system in which there is a need for development of forages to be used in a year-round forage system is during the period of time from late summer through late fall.

There are many possible backgrounding systems that may be derived using different cool season annuals, perennials, grasses or legumes. Some possible systems have been assembled that are workable in the Southeast. These systems may apply in some geographical areas and not in others. Not every system will work in every area of the Southeast. In all systems cattle used were weaned in October with the objective of achieving an arbitrary weight of approximately 700 lb. This would be the backgrounding period that was previously defined as being the period of time between weaning and prior to being placed on a finishing program. The first system is one in which the initial weight of the animals would be somewhere between 400-500 lb. These animals would start on the system in October at weaning and would end sometime in early April. In this system corn silage would be the basic forage. Corn silage could be fed at a rate of about 27.5 lb per day, along with 4 lb of ground shelled corn and 1.5 lb of protein supplement daily. Research has shown that this system will produce 1.6 or more pounds of daily gain. Using this system the producer could utilize the corn silage over a 180-day period after which the animal should weigh at least 700 lb and would be ready to go into a finishing program. This type of program would be adaptable to the livestock producer who has the capability to produce a high quality corn silage and has facilities necessary for a feeding system.

The second system that might be used would utilize a weanling calf weighing 400 to 500 lb starting October and ending in May. This could also be a corn silage program in which the animals were fed approximately 30 lb of corn silage with a protein supplement of 1.5 lb daily with expected daily gains in the range of 1 to 1.25 lb. This system would require approximately 250 days to get the animals to weigh in excess of 700 lb. This program would perhaps be less expensive if the producer had the capability of producing a good quality

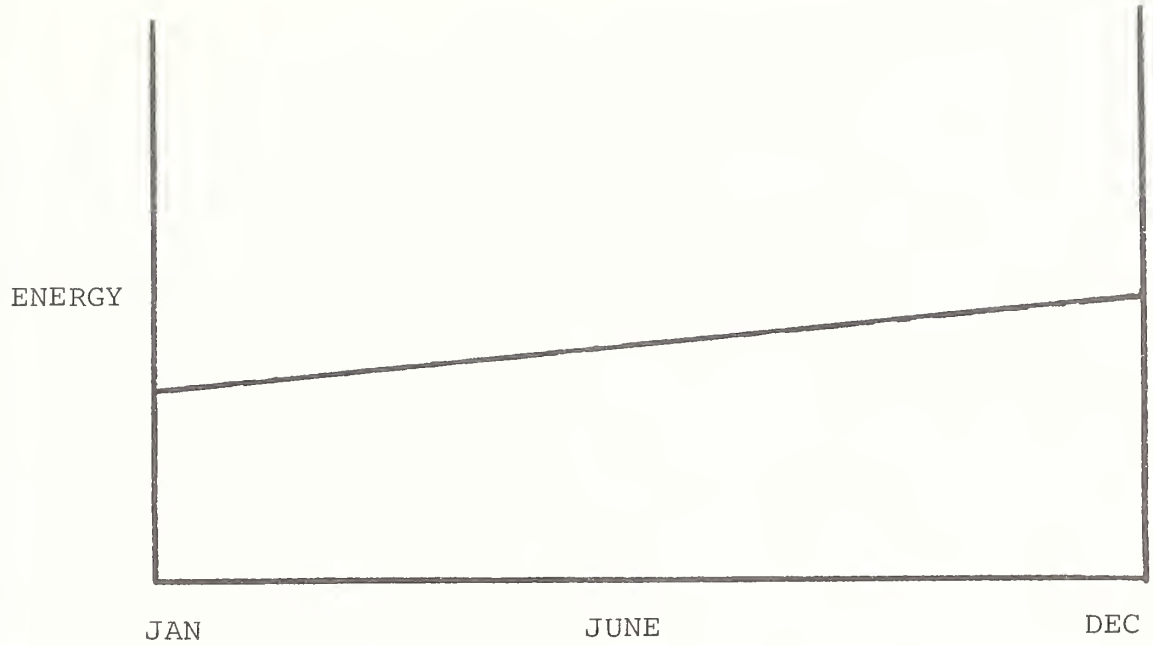

FIGURE 3.--Generalized energy requirement for a growing animal.

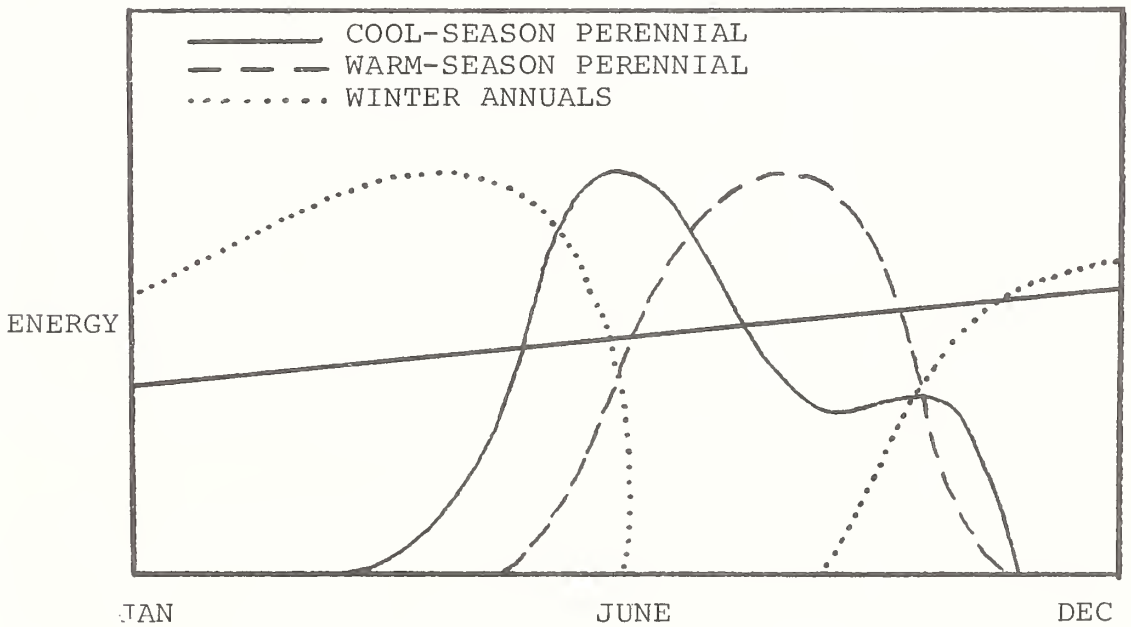

FIGURE 4.--Pasture availability curve and energy requirement for growth.

corn silage and did not have a need to move the animals at a quick rate in order to make room for other animals in a feeding operation.

The third system could be one in which the initial weight might range between 350 to 450 lb starting in October and ending sometime in July. This program would use a hay-corn-protein supplement regime from October through March. During this period the animals could be fed about 10 lb of a high-quality hay per day with 4 lb of ground shelled corn and 1.5 lb of protein supplement. The expected average daily gain would be about 1.35 lb per day from October to March. In April these animals could then be transferred to a perennial pasture consisting of bermudagrass-clover and be maintained on the pasture from April through July with an expected daily gain of at least 1.25 lb for the 120-day period. Again, by the end of July, the animal should weigh over 700 lb and be ready to be placed on a finishing program.

The fourth system outlined is one in which the initial weight could be between 400 and 500 lb, again starting in October and allowing for the animals to weigh above 700 lb by late June to early July. The animals could be maintained on a fescue-clover pasture at a rate of one animal per acre during the period from October to March. During the period from December to March, about 100 days, there would probably be a need for supplementing the calves with some hay and as much as 8 lb of grass hay and 1.5 lb of cottonseed meal might be required. It is anticipated that the calves would gain about .75 lb per day from October to March. Then from April through June, the animals could be maintained on the fescue-clover pasture at a rate of one animal per acre, with expected gains of 1.6 lb per head per day. These cattle would then be ready to be placed on a finishing program in late June or early July weighing in excess of 700 lb.

The fifth system that I have outlined would be one in which the initial weight might be from 300 to 400 lb and start in October and end in late June to early July. This system would require an adjustment period during October and November in which the animals could be placed on a fescue-clover pasture at the rate of one animal per acre with an anticipated average daily gain of about .3 pound. From December to February the animals could be changed to a wheat pasture at the rate of .75 acre per head. If a wheat-soybean rotation might be in the overall farm program, this would allow animal utilization of the wheat. During this period of time, there is the possibility that at least 30 days of feed may be required. This feed might be 8 lb of grass hay, 4 lb of corn and up to a pound of cottonseed meal. Gain during this period of time from December through February could be expected to be about 1.1 lb daily. During March the calves could be returned to the fescue-clover pasture with additional hay, if necessary, plus about 3 lb of corn and stocked at a rate of one animal per acre with an anticipated daily gain of about 1.5 pounds. From April through June the animals could be retained on the fescue-clover pasture at the rate of one animal per acre and average daily gains could be as much as 1.6 pounds. The animals should weigh about 700 lb by the end of June and thus, could then be placed on a finishing system.

System six utilizes animals weighing from 400 to 500 lb starting in October and ending in May. This system would utilize an adjustment period of bermuda and clover or fescue and clover during the months of October and November and stocked at a rate of one animal per acre. Average daily gain of about .3 or more lb per day would be expected. In late November to early December, the calves could be transferred to a cereal grain-ryegrass-clover pasture, stocked at a rate of about 600 lb of initial weight per acre. This would be one-and-one-half 400-lb animals per acre and maintained at this initial

stocking rate throughout the duration of the system. Depending upon the geographical area, there may be as much as a 30- to 45-day supplemental feed requirement. About 8 to 10 lb of hay and 1.5 lb of protein supplement would be needed during the months of January and February. During the supplemental feed period the average daily gains would drop perhaps as low as .75 pound. In March, April and May the cereal grains, ryegrass, annual clover would again display vigorous growth and gains during this period could be as much as 1.9 to 2.0 lb daily. These animals should weigh about 700 lb by the end of May and be ready to be placed on a finishing system.

The seventh system is one in which the initial weight might be as low as 300 lb starting in October and ending in late July or early August. In this system an adjustment period for the weaned animal would be to place the animal on a bermuda-clover or fescue-clover pasture at a rate of one animal per acre during the months of October and November. Expected daily gain for this period would be about .3 pound. From December to May the animals would be placed on a cereal grain-ryegrass-annual clover-red clover mixture with anticipated gain of 1.5 lb per day. During the months of January and February 30 to 45 days of supplemental feeding might be required. The supplemental feed might be hay or silage. About 10 lb of hay or hay equivalent and 1.5 lb of protein supplement could be fed with an anticipated average daily gain of .75 pound. In March, April and May the cereal grain-ryegrass-annual clover-red clover combination would be at its maximum productivity and average daily gains could be expected to go as high as 2.0 pounds. From the middle of May to the end of July the annual forage residue could be grazed along with the red clover and an expected gain would be about 1.6 lb per head daily. The animals that were started on this program should weigh in excess of 700 lb and would be ready to be placed on a finishing system by July.

I have listed several forage systems that might be used in a backgrounding program. I would, however, like to list some of the grazing systems that might be employed in the different backgrounding systems that I have just covered. Continuous grazing is the system that is quite often used in most of the winter annual grazing experiments. There is some evidence to indicate that rotational or strip grazing will increase the productivity of beef per acre. There are data from several institutions that have indicated that if a rotational grazing system is followed, that the beef production per land area can be increased by as much as 25 pounds per animal. There is also a recommendation that certain of the cool season forages be allowed to be deferred, which is nothing more than to allow forage to grow in one area, then place animals on the forage after it has obtained an abundance of growth.

I have listed a number of forage-livestock production systems that can be used. I would like to stress five "CANS" that should be considered in a forage production and utilization system. I think it is obvious that the producer CAN grow more forage. It is apparent that the producer should grow all the forage that he CAN. He should CAN all the forage that is produced, as to whether this be by an animal or in some type of structure or apparatus for future feeding, it should be harvested. The livestock producer should utilize all of the forage that he CAN. It is of little value to produce a forage and then not utilize it. The producer should sell all the forage through livestock that he CAN. Generally the most profitable means for selling forage is by taking the animal from weanling through a backgrounding system.

PRODUCING SLAUGHTER BEEF BY SUPPLEMENTING PASTURE

By M. B. Wise

Cattle finishing is a growing enterprise in the Southern United States. Increased demand for high quality beef and improvement of pastures have contributed materially to success in this area. Research at the North Carolina, Georgia, Louisiana, Alabama, Arkansas and Virginia Agricultural Experiment Stations has shown that one of the best methods of increasing returns from a cattle finishing program is the inclusion of high quality pasture as a major feed ingredient. Good quality pasture supplies most of the nutrients necessary for growth and finishing. Protein and vitamins are supplied in amounts that will meet the animals need. The primary nutrient which must be supplemented to grazing steers is energy. Also additional minerals may be necessary. The research reported herein revolves around the supplementation of energy to steers finished on pasture.

The "grain on grass" system takes advantage of our natural resources and furnishes a good return to land, labor and management. This system might also be characterized as a "low risk" system of finishing cattle. It requires a minimum of labor and is applicable to almost any size of operation which is able to produce excellent pasture. This system also minimizes the waste management problems encountered in dry-lot fattening.

Studies concerned with the feeding of grain on pasture have been conducted over a number of years. Early experiments at N. C. State University (Wise et al. 1965) involved a determination of the most economical level of grain to feed steers grazing clover-grass pastures. This work indicated that a level of 0.8 to 1% of the animals' body weight gave greatest financial returns (Table 1). Since the pasture season is a period during which most farmers are quite busy with other farm work, it was considered desirable to find a method which would allow self-feeding of grain on pasture without worry of the cattle overeating. Several studies showed that a mixture of 90% ground shelled corn and 10% animal fat was consumed by grazing steers at a level of about 0.8 to 1% of their body weight. Five experiments dealing with stilbestrol, showed that gains of grazing steers consuming the corn-fat mixture was increased from an average of 2.12 lbs. for control steers to 2.58 lbs. per day for steers implanted with 24 mg. of stilbestrol--an increase of 22%. The implantation of stilbestrol at the beginning of the fattening period also caused a decrease in concentrate necessary per pound of gain from 3.14 to 2.65. In other experiments, antibiotics were added to the corn-fat mixture and fed to one group of steers in each experiment. Other groups of steers received the corn-fat mixture without an antibiotic added. The addition of antibiotic (in this case Aureomycin) at a rate of 70 to 100 mg. daily resulted in an increase in daily gain of 0.1 lb. Although this was a small increase, the additional gain more than paid for the cost of the antibiotic. Research has also been conducted

which indicates that plant fats such as crude cottonseed oil may be used to limit the concentrate intake of grazing steers and that other grains such as milo may be used instead of corn. Green-chopping does not appear to be economically advantageous for fattening steers under present conditions in this area. Results also indicate that grass pastures supply sufficient protein for fattening steers fed an energy supplement of 90% corn with 10% fat, however, extra protein may be necessary under some conditions. A four year study (Wise et al. 1967) involving 304 steers (see Table 2) has also demonstrated that nitrated Coastal Bermudagrass may also be used in a "grain-on-pasture" program for fattening cattle. An extra source of protein is of questionable value in this system.

Subsequent studies at the North Carolina Station have demonstrated that the grain-on-pasture system is adaptable to the finishing of heifers, that Melengestrol Acetate (MGA) is useful in preventing estrus in these finishing heifers and that wheat can be used successfully as the supplemental energy source in the grain-on-grass system (Barrick et al. 1976).

Recent work at the Virginia Experiment Station (McClaugherty et al 1975) has been concerned with finishing steers and heifers in a system that maximizes the use of pastures consisting of blue grass orchard grass and white clover. This system takes advantage of the early spring "flush" of pasture and the fact that heifers normally finish earlier than steers. Steers and heifers in equal numbers were allowed 0.5 acres of pasture in mid-April and self-fed rolled corn with 10% added animal fat. In mid-July the heifers were marketed and the steers were allowed to graze the additional acreage vacated by the heifers giving them a total of one acre per head after that date. Results of studies during the three years are shown in Table 3.

The Virginia data demonstrate that this finishing system is adaptable to a blue grass, orchard grass, white clover pasture and that good use can be made of pasture for the entire summer season by a regulated marketing system.

Research at the Georgia station (Lowrey et al. 1972) has shown that grain feeding on pasture is applicable to the production of finished cattle during the winter season. Permanent pastures of cool season perennial species and temporary winter pastures consisting of small grains seeded in the fall were successfully used as the forage source. Highly acceptable gains and carcasses resulted when a grain mixture was offered ad libitum.

Research at the Louisiana Experiment Station has covered several areas of the use of pastures in finishing programs indicating a wide application of the grain-pasture system. A good example of this work (Carpenter, Klett, and Hembry, 1971) includes a 5-year study in which 450 pound steers were purchased in October and grazed for 299 days with various concentrate supplements. The pasture (a total of 1 acre per steer) consisted of equal acreages of fescue, Coastal bermudagrass and common bermudagrass. The Coastal and common bermudagrass was overseeded in November with common ryegrass. All pastures were well fertilized and nitrated. A period of 196 days (Nov. to May) was considered the winter period and 103 days (May to September) was considered the summer period. Five supplements containing varying amounts of ground corn, cottonseed meal, urea and limestone were used and salt was added to limit intake. All

treatments produced acceptable slaughter cattle as indicated in the combined winter-summer data. The Louisiana research demonstrates that a wide variety of rations can be successfully fed on pasture, that salt can be used to limit intake and that energy is the major nutrient that needs to be supplied in pasture fattening of cattle.

One of the major deterrents to the use of pasture in the finishing process is the slight yellowish tinge of the fat of the resulting carcass since some packer resistance is encountered. It should be noted that this yellowish cast is a result of carotene deposition and hence furnishes vitamin A to the consumer of this meat. Once the packer and consumer are educated to this fact much of the resistance tends to disappear.

SUMMARY

Research data from Experiment Stations and successful application by producers in the Southern United States have demonstrated that the use of limited grain on good pasture is an excellent method of finishing cattle. This system using concentrate intake limiters is applicable to both summer and winter growing forages, yields acceptable returns to land and capital, has a low labor requirement, and provides an answer to the waste management problems that are presently encountered in dry-lot systems. This system takes advantage of the tremendous capacity of the Southern United States to produce high yielding forage and is applicable wherever high quality forage can be produced.

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TABLE 1. Performance and concentrate intake and conversion of steers fed various energy supplements while grazing clover-grass pastures*. (North Carolina Experiment Station).

	Average Daily Gain Lb.	Daily Conc. Intake Lb.	Conc. Gain
A. Concentrate level - 1 experiment - 50 steers			
Corn, % of body wt:			
0	1.22	0	0
0.5	1.60	3.4	2.04
1.0	1.93	6.4	3.31
1.5	1.93	8.0	4.15
1.5 last 60 da	1.45	2.6	1.79
B. Intake limiters - 3 experiments - 130 steers			
Corn-hand fed	2.15	5.08	2.23
Corn + 10% salt	2.27	6.33	2.79
Corn + 10% fat	2.54	7.72	3.04
Corn + 10% animal fat	2.56	8.90	3.48
Corn + 10% cottonseed oil	2.62	9.94	3.79
C. Diethylstilbestrol - 5 experiments - 182 steers			
No stilbestrol	2.12	6.66	3.14
24 mg stilbestrol (implanted)	2.58	6.83	2.65
D. Antibiotic (Aureomycin) 3 experiments - 92 steers			
Corn + fat No antibiotic	2.27	5.85	2.58
Corn + fat 70-100 mg. antibiotic	2.37	6.33	2.67
E. Corn vs milo - 1 experiment - 36 steers			
Corn + 10% animal fat	1.85	9.24	5.00
Milo + 10% animal Fat	1.77	9.34	5.28
F. Green chop vs pasture - 2 experiments - 80 steers			
Pasture + corn with 10% fat	2.50	9.4	3.70
Green chop + corn with 10% fat	2.32	12.0	5.17

TABLE 1. Performance and concentrate intake and conversion of steers fed various energy supplements while grazing clover-grass pastures*. (North Carolina Experiment Station). (Continued)

	Average Daily Gain Lb.	Daily Conc. Intake Lb.	Conc. Gain
G. Protein sources - 2 experiments - 80 steers			
Pasture + corn-fat	2.76	11.26	4.08
Pasture + corn-fat + SBM (10%)	2.98	13.63	4.57
Pasture + corn-fat + N on sod (120#A)	2.65	9.91	3.74
Pasture + corn-fat + clover in sod	2.90	10.41	3.59

*In all experiments 600-700 pound calves were allowed .8-1 acre of Ladino clover-grass pasture and were fed minerals free choice. Minerals consisted of one box containing a mixture of 2 parts steamed bone meal (or dicalcium phosphate) plus 1 part T.M. salt and a second box containing plain salt.

TABLE 2. Performance of finishing steers fed various supplements while grazing nitrated Coastal bermudagrass. Averages of 4 year study (N. C. Experiment Station).

	Treatments[a]			
	P	P+E	P+Pr	P+E+Pr
Total steers/treatment	76	76	76	76
Av. no. days on experiment	163	163	163	163
Av. initial wt., lb.	682	671	677	671
Av. final wt., lb.	869	1025	906	1043
Av. gain/steer, lb.	187	354	229	372
Av. daily gain, lb.	1.15	2.16	1.40	2.27
Av. Daily concentrate, lb.	--	10.86	1.50	10.87
Concentrate/gain	--	5.03	--	4.79
Av. carcass grade[b]	8.3	10.1	8.5	10.1

[a]Treatments:
P= Coastal bermudagrass pasture (CB)
P+E = CB + 90% corn and 10% animal fat - self-fed
P+Pr = CB + 1.b lb/hd/day of soybean meal (SBM)
P+E+Pr = CB + 80% corn, 10% animal fat and 10% SBM - self-fed

[b]Based on 8 - high standard, 9 = low good, 10 = average good, 11 = high good, etc.

TABLE 3. Management systems for finishing steers and heifers with grain on pasture (Virginia Experiment Station).

	Average 1972, 1973 & 1974	
	Heifers	Steers
No. animals	36	36
Initial wt., lbs.	585	605
Wt. mid-July	751	802
Av. daily gain	2.37	2.81
Wt. mid-October	--	1015
Av. daily gain	--	2.44
Grain-fat/day, lb.	9.6	10.0
Grain-fat/lb. gain	4.1	4.1
Carcass grade[a]	9.9	10.4
Rind thickness, in.	.48	.65

[a]low good = 9, middle good = 10, high good = 11, etc.

FINISHING SLAUGHTER CATTLE WITH GRASS AND GRAIN

By John C. Carpenter, Jr.

A large amount of quality beef is consumed in Louisiana each year, but very little is produced. With the growing demand for beef and the economic pressures requiring greater efficiency, there is definitely a need for intensifying beef produced per cow and per acre.

Livestock producers in Louisiana and the southeastern United States are realizing more each year their advantage in forage production over other sections of the country. Our geographical location makes possible the production of both winter and summer pastures. While our summer pastures of bermudagrass, dallisgrass and bahiagrass have a high carrying capacity, the winter pastures of ryegrass, wheat and rye with clovers are our real bonus in the production of beef.

Because in many instances the economic return from the average weaned calf is insufficient to cover cow cost during the year, many beef producers are holding calves after weaning, grazing them, and either selling them as yearling cattle or carrying them to slaughter weights and selling them. In this way, the producer is essentially selling two calves per cow investment.

It is my belief that we should wean heavier calves and maintain ownership all the way to the rail. We have produced our heaviest calves by using a creep grazing area, especially for the calves, within each pasture unit. In a thirty acre area, divided into two tens and two fives, the cows had access to the twenty-five acres and the calves to the five acre creep anytime they wanted. Cows only grazed the creep area when it got ahead of the calves. Twenty-five cows and calves, four heifers and two bulls were carried on this thirty acres of pasture. Each year for four years, 15 tons of excess hay were produced. For four years, an average of the first two 205-day periods showed calves in this herd averaged 103 pounds heavier than calves in the herd where calves didn't have access to a special creep grazing area. In 1975, ten calves weaned on August 1 from this herd, averaged 579 pounds. The heaviest 700, and the lightest 455. In 1976, calves were not as heavy as in 1975, but there were a good many 600 to 670 pound calves from the four herds in the study.

At the Northeast Louisiana Experiment Station, St. Joseph, Louisiana, in earlier trials, it was found that beef calves fed a concentrate supplement while grazing fescue pastures, had a higher daily gain and slaughter grade than calves grazed without supplemental feed on the same type pasture. At the end of these trials cattle were graded on foot only and because of their light final weight, were sold as feeders rather than slaughter animals, so no carcass data were available (1).

Yearling steers fed a grain supplement either on coastal or common bermudagrass pastures had a higher daily gain and slaughter grade than non-fed steers. When graded on the live animal basis at the end of the trials, the fed steers graded Good to High Standard and the non-fed steers graded Standard. In two of the three trials, the fed steers graded Good to Standard on the carcass basis. When slaughtered, 58 percent graded Good and 42 percent Standard. Steers grazed without grain were not fat enough to suit the packers, so they sold as feeders and were fed in drylot prior to slaughter (1).

In earlier work at the West Louisiana Experiment Station, Angus steers were grazed on winter pasture for two years. Steers were approximately 18 to 30 months of age and weighed approximately 912 to 1092 pounds, and were graded 50 to 87 percent Choice. On these steers marketed in May, the fat was extremely yellow. In 1970 we looked at steers slaughtered at two years of age in February. The fat was not yellow, and approximately 50 percent of these steers graded Choice (2).

In the 1960's at the Northeast Louisiana Experiment Station at St. Joseph, concentrates were fed to steer calves grazing pasture for 300 to 350 days. Approximately one ton of feed was required per steer. Concentrates were fed to one group at a constant level of eight pounds per head daily and to the other group at one pound per head daily per 100 pounds of liveweight. Thus, the amount of concentrates fed to the latter group was increased with each 100 pound increase in body weight. The steers fed at the one percent level carried a higher degree of finish as observed after approximately 220 days in each trial. Forty-five percent of the steers in this group graded Choice when slaughtered, as compared with twenty percent in the group fed at the constant level during the trial. All carcasses exhibited superior marbling and rind fat that was fairly thin and white (3).

Using a ration containing 90 percent corn meal with ten percent salt, in three trials, beef steers averaged 1.77 pounds daily for 299 days. The ration intake averaged 6.80 pounds per head daily in addition to the pasture. The carcass grades averaged 10.4 (10 = average Good), which were lower than in previous trials where exactly one percent level was fed daily over the trial (4).

Following winter grazing at the Macon Ridge Branch Experiment Station, Winnsboro, Louisiana, steers were carried to slaughter weight and grade using grazing or green chop with and without grain. The lots receiving the grain with the grazing and green chop were slaughtered following the trial. The steers receiving the forage without grain were fed 55 days in drylot following the

grazing and slaughtered. Grazing and green chop alone produced fewer pounds of gain than when concentrates were added to the treatments. Green chop fed alone produced the lowest gain while grazing with concentrates produced the highest daily gain. In the 55-day drylot trials, the highest daily gains were produced by the steers previously fed green chop alone. The majority of these steers graded in the Good grade with a few Choice and Standard in each treatment (5).

We are now completing the third phase of a study comparing beef with forage alone, grain plus forage and drylot periods from 63 to 140 days. For two years, steers were marketed through one of the major chains and consumer acceptance evaluated. In trial 1, purchasers could not effectively distinguish in tenderness, flavor and juiciness between grass fed beef and beef from animals fed up to 108 days in feedlot. The highest percentage of consumers willing to repurchase at a higher price chose the forage fed beef (6).

In phase 2, animals were slaughtered at a younger age and the forage fed animals were lighter and not carrying the finish as in phase 1. They were marketed in the fall instead of in February. The drylot steers were fed 70 or 140 days and produced higher quality carcasses with a greater percentage grading Choice than the forage fed or grain on grass lots. On the basis of cutability and quality, the 70-day treatment produced the most desirable carcasses. Results from the retail consumer ratings showed differences among treatments for tenderness and flavor. The 70-day feedlot steers received the best ratings, while the forage steers received the poorest ratings (7).

Most of the animals in phase 3 have been slaughtered. The four treatments used were (1) forage alone, (2) grass plus one percent grain for 232 days, (3) grass to 850 - 70 days in drylot, and (4) grass to June 1, one percent grain added 60 days, then drylot to 1050 pounds. All treatments weighed approximately 1050 pounds when slaughtered. Carcass grades were as follows: Lot 1 - 1 Choice, 5 Good, 1 Standard plus; Lot 2 - 7 Choice, 7 Good; Lot 3 - 10 Choice, 3 Good, 1 Standard plus; and Lot 4 - 2 Prime, 8 Choice, 3 Good, 1 Standard. The last seven grass steers will be slaughtered in April.

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USE OF LIMITED GRAIN FOR FINISHING STEERS ON PASTURE

By Maurice L. Ray and A. E. Spooner

Research has been conducted for several years at the Arkansas Agricultural Experiment Station relative to various aspects of backgrounding and/or finishing steers on pasture using a minimum of grain. Current Arkansas research concerning the use of limited grain for finishing steers on pasture is being conducted at two locations. Research at both stations involves backgrounding and finishing fall born beef steers weaned in late summer. These steers are subsequently backgrounded through the fall and winter months (about 180 days) and then finished on pasture as long yearlings during the spring and early summer (60 to 80 days).

Dr. Spooner and I plan for each study to span a minimum of four years to minimize the bias in data imposed by unusual seasonal weather variations. The past two years have certainly borne out the need for additional years as rainfall patterns have been quite erratic. Today rather than present detailed data, some of which we would consider incomplete, I would like to discuss in general factors Dr. Spooner and I consider to be paramount for successful finishing of young beef animals on pasture. Perhaps these can elicit some discussion among participants of this conference that will be helpful to everyone.

First, forage species and combinations must be carefully selected and managed. As an example, tall fescue and white clover although not equal in quality to wheat, rye, ryegrass and arrowleaf clover combinations as measured by average daily steer gains has produced more gains per acre than the annual small grains due to greater grazing days and carrying capacity.

We have experienced considerable difficulty at our Beef Substation in East Central Arkansas in getting small grains seeded early enough to obtain sufficient growth to give more than 30 to 45 days fall grazing before the steers must be moved to another feeding regime for the remainder of the winter. Fescue and clover has generally carried steers at least 30 days farther into the winter.

Another example, ryegrass alone or with white clover has been very erratic for us; often providing almost no fall and winter growth. It has often produced very well in spring and early summer; however, at this time of year it is not difficult to obtain gains of three pounds or more per day on most of our pastures if supplemented by grain.

Second, we have satisfied ourselves completely that we cannot finish modern beef steers, many of whom contain "exotic beef breeding", at under 24 months of age unless grain is fed on grass.

It has become obvious to us that the higher percentage of the blood of the major British breeds the higher the percentage of choice carcasses we obtain.

Third, animal selection and management is highly important to success in finishing steers on grass particularly within the farmework of our studies. Calves started at under 500 pounds have been much more difficult to fatten to choice finish on grain and grass than calves started at 550 to 600 pounds.

Fourth, in the backgrounding phase we have found a tendency on our part to leave the calves on pasture too long in the fall. Frequently the last two or three weeks of fall grazing has resulted in a loss of much of the weight that had been gained previously.

Fifth, regular internal parasite treatment (approximately every 90 days) has been very important to us. We have found that the burden of internal parasitism has often reduced gains even though clinical signs of parasitism have been minimal or absent.

Sixth, excessive clover growth in the spring of 1976 apparently contributed significantly to a very high percentage of carcasses with objectionable yellow fat. At least these two phenomena occurred at the same time in 1976 and has caused us to go back to the literature and to initiate plans to study possible cause and effect relationships in this regard. Carcasses produced in 1976 were the first to have objectionable levels of yellow fat that we have encountered since our studies of finishing steers on grass began in 1965.

Seventh, data obtained from the first two years of a study at the Southwest Branch Station (Hope) in which we have varied the time grain feeding was started and the level of grain fed to steers on tall fescue and clover interseeded into bermudagrass sod have indicated to us that grain supplementation at the level of .5% of live weight will not give adequate backgrounding gain. The level of 1.0% throughout the entire backgrounding period has produced greater total gain than withholding grain the first half of the backgrounding period and then giving 2.0% during the final 90 days prior to the finishing period. It must be pointed out, however, that the fall seasons have been drier than usual in both years. We believe that with adequate moisture grain supplementation may not be necessary for the first 90 days of the fall and early winter backgrounding period.

CONTROL OF INTERNAL PARASITES IN ANIMALS ON PASTURES

By H. Ciordia

Domestic animals are subject to parasitism by many species of parasitic nematodes. The extent of parasitism is determined by a number of factors such as weather, pasture and grazing management, and the physiology and condition of the animal. Knowledge of epizootiology of nematode parasites is necessary in order to develop a broad control program. Unlike bacterial infections, nematode parasites of domestic animals cannot multiply within the host; each generation must undergo some development outside the host before reentering and once again adopting a parasitic existence.

The role of internal parasites in the economy of livestock production can be measured by the estimated losses attributable to the depredation of these pests. In a recent publication by the U. S. Department of Agriculture, the annual loss due to mortality and morbidity caused by internal parasites was estimated to be over $162 million (1). Parasitism is significant in young or poorly managed livestock. Under farm conditions, parasitism exists primarily subclinically and, therefore, produces unnoticed economic losses. The economic losses or costs per cattle farm reported from South Georgia (3) in 1962 were $570 for sickness, $977 from death, and $121 for anthelmintic medications, a total annual cost of $1,668 for internal parasites per beef cattle farm. Of even greater concern are the results of a survey conducted in Georgia which indicated that parasitism has increased steadily during the last 15 years (2).

The prevention of parasitic infection is primarily a management problem based on the available knowledge of the life cycle of the round worms. The life cycle chain is most easily broken at its weakest link -- in this parasite, the free-living stages. Treatment of the host animal with chemicals is therapeutic, not preventive. To break the life cycle, management must have knowledge of some of the field factors, such as temperature and moisture, which are necessary for development, migration, and survival of the larvae. The larvae in Georgia are provided with adequate temperatures for development during most of the year. On the basis of available knowledge, some management factors must be used in an attempt to reduce parasitism.

Pasture Management

Overstocking. With improved pastures, the tendency is to concentrate more cattle per acre and thus increase the amount of cattle droppings and the potential parasite load of the pasture. Our work has shown that increasing the concentration of cattle on improved pasture resulted in greater parasite

contamination of the pasture and greater infection of grazing animals (8). Thus, average daily weight gains (A.D.G.) and carcass grades were lower in cattle from overstocked pastures than in cattle from moderately stocked or understocked pastures (Table 1).

Overstocking will result in overgrazing, which will bring about a more rapid increase of the round worm population. But overstocking is not considered to be as significant as nutrition. We can say, with reservation, that if the nutritive value of the improved pasture is much better than that of the unimproved pasture, then increased stocking rate does not necessarily result in clinical signs of parasitism.

Overgrazing. Close grazing results in heavier infections of parasites because grazing cattle will pick up greater number of parasitic larvae, which are usually concentrated on the bottom 5.8 centimeters of the pasture grass. When the pasture is short and scarce, the cattle will spend more time grazing to consume the required amount of food. This factor will increase the possibility of ingesting more larvae because cattle will graze during the periods of optimum larval migration, which coincide with an increase in the humidity from dew deposits on grass blades or with actual rain. Also, in short forage pasture, cattle will graze a much larger area in order to satisfy their food requirements. This type grazing will also increase their opportunity to pick up infective larvae. Furthermore, to be ingested, the larvae need to climb a much shorter distance on the short grass than on forage of average height.

The above observations may be complicated by several factors. For example, in hot, dry weather, a closely grazed pasture may result in greater kill of either parasite eggs or larvae, or both, because of increased heat and evaporation. Consequently, in theory, overgrazing may be a desirable parasite control practice, whereas high forage may protect the eggs and larvae during the summer. Moreover, grass allowed to grow too tall, especially if it goes to seed, has low nutritive value, which may make the animals more susceptible to parasitism. As grass grows taller, particularly in continuously grazed pasture, cattle searching for more succulent, palatable grass tend to confine their grazing more and more to areas that have previously been grazed closely. Consequently, these cattle may pick up more parasites from an undergrazed pasture than from one more closely grazed over its entire area.

Studies conducted at the Georgia Experiment Station (4) clearly showed that cattle on an overgrazed pasture had many more roundworms when slaughtered, made lower A.D.G., and had lower carcass grades than those on a moderately grazed or undergrazed pasture (Table 2). These results point out the potential epizootiological danger of overgrazing pastures. This danger is increased when the nutritive value of the forage is below the required level. In our 3-year study, nutritive values of the forages was not below the required level.

Rotation of animals on pasture. Because of the continuous buildup of larval parasites, permanent pastures can promote a high level of parasite infection in stock grazed on them, especially bermudagrass and fescue grass pastures. Larvae can survive for longer periods in these grasses than in others, probably because of the protection afforded by the thick matting of these grasses. The area used as a permanent pasture probably should be divided into sections to be grazed rotationally, and thus allow the undergrazed sections to "rest". In theory, this resting may aid in the control parasites and provide more nutritive forage. The length of the resting period for each dection depends on weather conditions. For example, in the summer, a relatively short resting period will usually suffice, for the larvae will succumb to

the heat and to dry conditions more quickly then than during other seasons.

The rotation of animals probably is not as critical on a temporary pasture as on a permanent one. Temporary pastures entail plowing that should eliminate more parasite eggs or larvae that may have been present. A resting or non-contaminated period also is provided. We have found very little larval carryover from one grazing season to the next on temporary pasture. In addition to this low carryover the temporary forage usually provides high quality nutrition, that in itself is a good control of parasites.

Three tests conducted during 3 consecutive years in Georgia (7) showed that rotationally grazed beef steers had the largest number of internal parasites whereas the continuously grazed steers, on the same type of winter temporary pasture, had the lowest number of worms. Continuous grazing consistently resulted in higher A.D.G. than did the rotational grazing; however, rotational grazing resulted in higher stocking rates, higher gains per hectare, larger numbers of round worms, greater net return, and less cost per unit of gain than did continuous grazing (Table 3).

If infected animals are to be moved to a clean pasture, a good practice is to treat them for parasites before transfer. This treatment will delay the contamination of the new pasture.

Soil preparation. Nematode larval population of pasture is reduced by turning the land (plowing or disking). This measure is especially advantageous in permanent pastures such as bermudagrass and fescue. The round worm population is lower in animals grazing renovated fescue than in those grazing a permanent fescue pasture. Also, harrowing or dragging contaminated pastures possibly aids in the destruction of larvae because the piles of manure are scattered and dry faster. On the other hand, in rainy or cool seasons, scattering manure droppings may actually spread the infective larval stages.

Pasture fertilization. The amount of forage available for grazing cattle is dependent, along with other factors, on the amount of fertilizer applied to the pasture. Results in an experiment in cooperation with the Southern Piedmont Conservation Research Center, Watkinsville, Georgia, indicated that fertilization increased the amount of forage available, which, in turn, decreased the level of parasitism in cattle.

Use of poultry litter on pastures. Two tests in Watkinsville, Georgia showed that parasitism in cows and their calves on tall fescue pasture fertilized with poultry litter was lower than parasitism of cattle on fescue fertilized with NH_4NO_3. Evidently, poultry litter may be used on pastures without epidemiological implications. This practice may provide cattle growers with a profitable practice, with important ecological benefits to poultry growers.

Animal Management

Nutrition. Of all the preventive measures available, proper nutrition is probably the most important. In our experimental studies, no serious parasite problem was met as long as the cattle were on an adequate plane of nutrition. Enough pastures for grazing animals or for supplemental feed must be provided. Sufficient nutritionally balanced feed is the best treatment for parasitism probably because of the interaction of nutrition and host resistance.

The species and type of grass and the quality and quantity of the available pasture can influence the parasite population of grazing animals. Our work (5) has indicated that calves on pastures with different species of

grass differ in the number of internal parasites recovered (Table 4). More roundworms have been found in calves on fescue grass than in those on rescue grass, ryegrass, crimson clover, or a winter temporary mixture (rye, wheat, ryegrass, and crimson clover). Also, more infective larvae were recovered from grass clippings from fescue pastures than from clippings from comparable pastures planted with a temporary winter mixture or with ryegrass-crimson clover (10). In each of the experiments, the nutritional level provided by each forage probably was an important factor in the difference between the performance and round worm populations of the groups of calves. The combined effects of the lower nutritive value of fescue and the greater round worm population produced lower weight gains in the animals.

Supplemental feeding of calves on pasture is advantageous in reducing the danger of parasites among calves. In an experiment conducted at our station, a corn supplement increased the weight gains and the carcass grades and reduced the number of nematode parasites in beef yearlings (Table 5).

Earlier tests (9) also showed that calves given corn supplement while on three types of pastures generally had fewer round worms than those on the same type of pasture without corn supplement. The difference was especially noticeable in the groups on fescue (Table 6).

In other experiments, a corn supplement significantly inhibited development of eggs and larvae of cattle nematodes in feces (6). Thus, corn has a twofold effect on parasitism: (1) it increases the nutritional level to provide the host with the immunological tools to fight the invasion; and (2) it reduces the seeding of the pastures with infective larvae.

In addition to the nutritional effect of the various pastures on parasitism in calves, pastures may differ in their direct effect on the development, survival, and migration of the free-living stages and in their indirect effect on the development of the parasitic stages of the nematodes. For example, the type of forage growth may facilitate or inhibit larval migration, whereas the height or density of the forage affect the adequacy of protection provided the larvae against the vagaries of weather and may control developmental rate and survival.

Mixed grazing. Animals of different ages should not be grazed together because younger calves are more susceptible to parasites than are older animals. The incidence of roundworm infections is low in calves 2 to 3 months old, probably because of their lack of exposure, because milk comprises most of their diet and forage comprises very little. The number of infected animals increases rapidly up to 9 months of age and then apparently more slowly until just about all are infected. Under proper management and nutrition, the incidence of round worms decreases after cattle are 18 months old.

Health. Diseased animals are more susceptible to parasitic infections than are healthy animals; consequently, cattle should be maintained in good health.

Sanitation. Because the eggs and larvae of parasites are found in the manure, an effort should be made to prevent its accumulation in barns, in sheds and around watering places.

Inheritance. Some workers (11) have shown that by selective breeding we may be able to create populations of cattle resistant to some internal parasites. However, tested resistant animals are not readily available on the market.

Host resistance. Generally, pastures free from parasitic larvae would

seem desirable; however, cattle can and do develop some degree of resistance to these parasites if the animals are not exposed to many larvae. When later exposed to infective parasitic larvae, such partly-immunized cattle will have fewer round worms than do cattle with no previous parasite exposure.

Treatment

When control of parasitism through prevention is not practical, the animals should be treated with anthelmintic (de-wormer) drugs. Treatment alone cannot be relied on to check outbreaks or to cure weakened animals. Treatment is most efficiently used as an adjunct to other control measures rather than as a substitute for them. Parasitism is essentially a herd disease rather than a condition of one or several animals although some individual animals may be more resistant and others more susceptible to parasitism.

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TABLE 1. --Effect of Three Stocking Rates on Parasitism of Yearling Calves on Winter Temporary Pastures (3-Year Average).

Stocking rates	A.D.G.* (kg)	Carcass grades**	Av. no. worms
Understocked pasture (1.0 calves/acre)	1.02	10.6	5,330
Moderately stocked pasture (1.25 calves/acre)	0.91	9.5	26,979
Overstocked pasture (1.50 calves/acre)	0.85	9.0	38,429

*A.D.G. = Average daily gain
**Average: Good = 10, choice = 13.

TABLE 2. --Effect of Three Grazing Intensities on Parasitism of Yearling Calves on Winter Temporary Pastures (3-Year Average).

Item	Over-grazed pastures	Moderately grazed pastures	Under-grazed pastures
Average stocking rates	2.53	1.90	1.37
A.D.G.* (kg)	0.70	0.85	1.08
Carcass grades**	6.14	6.86	7.57
Average No. roundworms	164,831	62,629	30,027

*A.D.G. = Average daily gain.
**Averages: Standard = 7, Good = 10.

TABLE 3. --Effect of Continuous vs. Rotational Grazing of Yearling Calves on Winter Temporary Pastures.

Item	Continuous grazing	Rotational grazing
Av. stocking rate (ha)	2.67	3.61
A.D.G.* (kg)	1.07	0.93
Gain/hectare (kg)	469	531
Average no. round worms	23,092	37,691
Return/hectare, $	115.97	159.19

*A.D.G. = average daily gain

TABLE 4. --Effects of Pasture Types on Parasitism and Weight Gains of Yearling Calves.

Item	Temporary pasture	Fescue pasture	Renovated fescue pasture
No. round worms/calf	70,964	83.609	30,211
A.D.G.* (kg)	0.70	0.48	0.72
Stocking rate (ha)	3.46	2.77	2.57

*A.D.G. = average daily gain

TABLE 5. --Effects of Two Types of Winter Pastures and Supplemental Feeding on Parasitism and Weight Gains on Beef Yearling Calves.

	Temporary pasture		Rescuegrass pasture	
Item	No corn	corn	No corn	corn
A.D.G.* (kg)	1.16	1.31	1.40	1.51
Carcass grade	7.00	7.38	7.00	7.57
Av. no. worms	50,126	16,216	30,345	14,439

A.D.G. = average daily gain

TABLE 6. --Effects of Supplemental Feeding and Three Types of Winter Pasture on Parasitism and Weight Gains of Yearling Beeves (2-Year Average).

	Type of pasture					
	Fescue		Temporary		Crimson clover	
	No corn	corn	No corn	corn	No corn	corn
A.D.G.* (kg)	0.63	1.04	1.20	1.21	1.08	1.07
Av. no. worms	75,250	21,000	13,500	3,500	24,250	7,500

*A.D.G. = average daily gain

CURRENT STATUS OF INFRARED REFLECTANCE

By J. S. Shenk and R. F Barnes

The need for a method to evaluate forage quality that is rapid, inexpensive, accurate, and precise has long been recognized (1). The use of near infrared reflectance spectroscopy to predict the chemical and nutritional composition of forage and feed grains has been proposed (2, 3, 4, 5). The information reported thus far for forages has been obtained with infrared spectro-computer systems (IRSCS). These systems use a scanning monochromator capable of taking measurements at as many as 8,000 different wavelengths in the region from 1.0 to 2.6 μm. Commercial instruments do not have this capacity. Newer models being developed will have the capability to take measurements at more wavelengths.

The purpose of this paper was to assess the effectiveness of the wavelengths (filters) proposed for cereal grains or forages (2) to predict various quality components in forages and feedstuffs. IRSCS analysis with multiple wavelengths was included for comparative purposes.

MATERIALS AND METHODS

A wide range of feedstuffs grown at different locations and in different years was chosen for this study. Samples were prepared for analysis by drying to 92 to 95 percent dry matter and grinding through a 1 mm screen in a Wiley Mill. Samples were analyzed in duplicate by the Kjeldahl procedure for nitrogen and converted to percentage protein by the appropriate factor. Digestibility was estimated by the *in vitro* procedure. Procedures for collecting the animal data for the forage samples have been reported (2, 6).

Reflectance data were collected by monochromator every 20 A between 1.05 to 2.55 μm for each sample (a total of 751 data points). Forage samples were analyzed by IRSCS in duplicate with single determinations for the cereal grains. Infrared (IR) data were recorded and analyzed as log (1/R), where R equals reflectance. Data were averaged for each sample and used for calibration. The IR data from the six wavelengths proposed for grains (1.68, 1.94, 2.10, 2.18, 2.23, 2.31 μm) or forages (1.672, 1.70, 1.94, 2.10, 2.18, 2.336 μm) were then used to develop calibration equations for each group of samples. Some bias may be associated with this simulation of commercial instrument filters, but we believe these results are useful for general comparisons.

Wavelengths for the IRSCS comparison were selected by multiple stepwise regression and added or deleted from the calibration equation on the basis of a partial F test. The minimum value selected to prevent wavelength additions by chance was 8.0. Standard deviations for protein and *in vitro* digestion of

TABLE 1.--Comparison of simulated protein and *in vitro* digestion calibration of forages and cereal grains when commercial wavelengths and the spectro-computer were used

Feedstuff	Sample No.	Protein			*In vitro* Digestion[1/]		
		σ[2/]	SEC[3/]	R^2	σ[2/]	SEC[3/]	R^2
Temperate forages[4/]	117	5.15			8.07		
Grain filters			0.79	0.98		3.27	0.83
Forage filters			0.79	0.98		2.79	0.87
Spectro-computer			0.69	0.99		1.89	0.95
Tropical grasses[5/]	29	4.45			11.01		
Grain filters			0.95	0.96		5.25	0.82
Forage filters			0.99	0.96		3.23	0.93
Spectro-computer			0.62	0.98		1.46	0.99
Corn silage[6/]	91	1.27			2.29		
Grain filters			0.52	0.84		1.86	0.35
Forage filters			0.48	0.87		1.56	0.53
Spectro-computer			0.40	0.91		1.36	0.62
Corn grain[7/]	61	0.69			2.77		
Grain filters			0.24	0.89		2.31	0.46
Forage filters			0.24	0.89		2.09	0.61
Spectro-computer			0.21	0.91		1.73	0.62
Oats[8/]	67	1.54			3.31		
Grain filters			0.47	0.92		1.73	0.75
Forage filters			0.49	0.91		1.50	0.81
Spectro-computer			0.42	0.92		1.39	0.84
Wheat[9/]	55	2.30			1.17		
Grain filters			0.35	0.98		0.81	0.37
Forage filters			0.38	0.98		0.78	0.38
Spectro-computer			0.37	0.98		0.76	0.39
Barley[9/]	31	1.46			1.73		
Grain filters			0.49	0.91		1.43	0.45
Forage filters			0.44	0.93		1.44	0.44
Spectro-computer			0.25	0.98		1.14	0.59

[1/] Digestion of tropical grasses was estimated with a 72-hour *in vitro* organic matter disappearance procedure. All other samples were analyzed by the *in vitro* dry matter disappearance procedure.

[2/] σ = Standard deviations of all samples.

[3/] SEC = Standard error of calibration.

[4/] Samples provided by R. F Barnes and W. N. Mason

[5/] Samples provided by J. E. Moore

[6/] Samples provided by J. E. Baylor

[7/] Samples provided by J. H. McGahen

[8/] Samples provided by H. G. Marshall

[9/] Samples provided by R. P. Pfeifer

each crop are found in Table 1; similar data for animal measurements are shown in Table 2.

RESULTS AND DISCUSSION

Comparisons of the calibration statistics for forages indicate that both the grain and forage wavelengths can be used to predict forage protein (Table 1). This is because the protein reference wavelength, 2.10 μm, and the protein wavelength, 2.18 μm, were used in both calibrations. However, the *in vitro* digestion standard errors of calibration (SEC) and the corresponding R^2 values are consistently better for the forage wavelengths than for the grain wavelengths when the 1.672 μm wavelength is substituted for 1.68 μm, the 1.70 μm for 2.23 μm, and the 2.336 μm for 2.31 μm.

Protein calibration statistics for cereal grains are slightly larger than those reported by Williams (7) because calibration was accomplished over a wide diversity of locations and growing conditions. Nevertheless, both forage and grain wavelengths gave very similar results, an indication that the three wavelengths that differed among these sets did not interfere in the calibration. The oat samples exhibited the largest standard deviation in digestibility for grains, and here again the forage wavelengths had a consistently lower SEC and higher R^2.

Results with IRSCS suggest that some lowering of standard errors can be accomplished by adding additional wavelengths to predict each constituent. IRSCS calibrations contained from 3 to 10 different wavelengths for each constituent and group of samples.

The prediction of animal response with the forage wavelengths was not very acceptable (Table 2). However, the spectro-computer results indicated that further improvement in prediction will be possible if more appropriate wavelengths are chosen to predict animal performance as has been shown with protein and *in vitro* digestion. Also, tropical forages may require a different set of wavelengths though compromise wavelengths may be found that will be acceptable for both temperate and tropical forages. The biggest problem is obtaining enough animal data over locations, species, varieties, and growing conditions to determine the appropriate wavelengths.

To test the size of the standard error of predicting the protein and digestion of samples not used in the calibration, we split the temperate forages and all of the 214 grain samples into two equal size groups on an every other sample basis. The first group was used to derive the calibration (C) equation, the second to test the equation (P) (Table 3). The general agreement between C and P indicates the accuracy of the calibration equation in predicting the protein and digestibility of these crop species. Also, calibrations of grains within species appear to be more accurate than across species.

CONCLUSION

The results suggest that properly calibrated instruments fitted with six wavelengths (1.672, 1.70, 1.94, 2.10, 2.18, 2.336 μm) should be able to

TABLE 2.--Comparison of simulated intake (I), digestibility (D), and digestible intake (DI) calibration for sheep when commercial wavelengths were used for forages and the spectro-computer

Forages	I			D			DI		
	σ[1/]	SEC[2/]	R^2	σ[1/]	SEC[2/]	R^2	σ[1/]	SEC[2/]	R^2
Temperate forages[3/]	16.58			7.09			11.75		
Forage filters		7.83	0.59		3.44	0.80		8.79	0.74
Spectro-computer		6.24	0.73		2.16	0.92		6.81	0.84
Tropical forages[4/]	12.22			7.93			9.52		
Forage filters		7.20	0.73		2.74	0.91		4.00	0.86
Spectro-computer		4.99	0.85		1.69	0.96		3.13	0.90

[1/] σ = Standard deviation of all samples.
[2/] SEC = Standard error of calibration.
[3/] 62 samples provided by R. F Barnes
[4/] 29 samples provided by J. E. Moore

TABLE 3.--Comparison of the statistical errors associated with temperate forage and cereal grain samples used for calibration (C) and prediction (P) of protein and *in vitro* digestion

Feedstuffs	Sample No.	σ[1]	Forage Wavelengths SE[2]	Forage Wavelengths R^2	Spectro-Computer SE[2]	Spectro-Computer R^2
Temperate forages						
Protein						
C	59	5.42	0.89	0.97	0.78	0.98
P	58	4.89	1.00	0.96	0.85	0.97
In vitro digestion[3]						
C	59	8.32	3.15	0.87	1.96	0.95
P	58	7.96	3.37	0.83	2.45	0.92
Cereal grains						
Protein						
C	107	2.71	0.73	0.93	0.44	0.98
P	107	2.71	0.77	0.92	0.55	0.96
In vitro digestion[3]						
C	107	9.76	2.24	0.95	1.95	0.97
P	107	10.11	2.44	0.94	2.10	0.96

[1] σ = Standard deviation of samples
[2] SE = Standard error
[3] *In vitro* digestion was estimated with the *in vitro* dry matter disappearance procedure.

predict the protein of cereal grains with a standard error between 0.2 and 0.5 percent, and predict *in vitro* digestion with a standard error of <2.0 percent. The standard error of prediction of forage protein would be approximately 1.0 percent, and that for *in vitro* digestion between 2.5 and 3.3 percent. Standard errors of this magnitude will be useful for some but not all applications. Prediction of animal response will require further refinements in instrumentation and selection of wavelengths.

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BREEDING STOCKS AVAILABLE AT REGIONAL PLANT INTRODUCTION STATIONS

By W. R. Langford

Abstract

Upon passage of the Research and Marketing Act in 1946 four regional plant introduction stations were established in the United States to support the regional new plants projects. These stations are operated cooperatively by the State Agricultural Experiment Stations and the Agricultural Research Service. Although plant introduction in the United States dates back to the colonial period and the present Plant Introduction (P. I.) numbering system to 1898, prior to 1946 there was no organized program to maintain materials after introduction. Since 1946 the four regional stations have accumulated 105,000 accessions representing more than 700 plant genera and several thousand species. Although our country is deficient with respect to native crop plants, plant breeders in the United States now have easy access to a greater diversity of germplasm than do their counterparts in any other country. Sizable collections of most forage crops grown in this country are held at one of these four stations. Some collections held at Experiment, Georgia are: bluestems, Cenchrus, Chloris, Cyndon, Digitaria, Panicum, Paspalum, annual Trifolium spp., Medicago, and Vicia. The Northeastern Regional Station maintains perennial Trifolium spp., Lotus, and Phleum. Perennial Medicago spp., Bromus, Melilotus, and Coronilla are held at Ames, Iowa; and the Western Regional Station maintains Festuca, Dactylis, Lolium, Agropyron, and Eragrostis. Propagating material of all of these is available to plant scientists upon request.

Through plant exploration and international exchange of plant germplasm new introductions are added to these collections annually. Explorations will be conducted this year to collect (1) grasses in the U.S.S.R.; (2) clovers in Greece, Yugoslavia, and Italy; and (3) Leucaena in Mexico and Central America. When there is need for additional germplasm, requests for explorations should be submitted in project outline form to the S-9 Technical Committee. Requests from all 4 regions are reviewed at the national level by the ARS Plant Germplasm Coordinating Committee. Proposals that are approved by the ARS committee are recommended on a priority basis for funding.

POPULATION IMPROVEMENT BY RECURRENT RESTRICTED PHENOTYPIC SELECTION

By Glenn W. Burton

Population improvement involves increasing the frequency of desirable genes. To accomplish improvement:

1. The initial population must have a desirable-gene-frequency of less than 1.0.
2. The desirable genes must be identifiable.
3. Individuals carrying desirable-genes must be selected for the next generation.
4. To avoid inbreeding depression, a large number of unrelated plants carrying desirable genes must be intermated in each generation.

Mass selection is the oldest method of population improvement. Early man, without knowledge of genetics, used it to develop our crop plants from their wild progenitors. Mass selection involves isolation of desirable genes on the basis of their phenotypic expression. Highly heritable characters, such as maturity respond to phenotypic selection more rapidly than yield, a character that usually has a low heritability.

Recurrent restricted phenotypic selection (RRPS) is an improved modification of mass selection as generally practiced (Burton, 1974). With four two-year cycles of RRPS, we were able to advance the forage yield (in replicated seeded plots) of Pensacola bahiagrass a mean of 17.7% - 2% per cycle for the previously selected narrow-gene population and 6% per cycle from the unselected wide-gene population. The variances remaining in the populations indicate that forage yields can be further increased with additional cycles of RRPS.

The six restrictions in RRPS that improve the efficiency of mass-selection for yield improvement are as follows:

1. When possible we choose germplasm with a high degree of self-incompatability but good cross-compatability to reduce the likelihood of selfing. This restriction (normal in Pensacola bahiagrass) is good but not necessary.

2. We divide the 1000-plant spaced population into 25-plant square plots and select the best five plants in each plot to reduce soil heterogeneity effects and faciliate visual selection in lieu of taking forage yields.
3. Instead of using open-pollinated seed from the 200 selected phenotypes to plant the next cycle, we intermate them in isolation to produce seed for the next generation. This procedure doubles the rate of advance by imposing paternal as well as maternal selection.
4. We greatly facilitate intermating and gene recombination by bringing together in isolation two culms (ready to flower the next day) from each phenotype. These culms, placed together in water in the laboratory, are in such intimate association that agitation each day ensures maximum cross-pollination.
5. We use 2 culms from each selection to provide equal representation and ensure that each will be represented should one culm fail.
6. We keep the intermated seeds from each of the 200 selections separate and plant enough for 100 plants of each in a single row in flats of sterile soil in the greenhouse in December. When old enough to transplant, we pull the whole row and select the five largest plants to set in sterile soil in 5-cm clay pots. (It is well to have an extra plant potted to insure against loss). This procedure helps keep the gene base wide and gives a combined seedling spaced-plant population of 20,000 plants.

A more detailed description of a single cycle of RRPS currently practiced in Pensacola bahiagrass improvement follows.

One thousand 4-month old seedlings grown in 5-cm pots under uniform greenhouse conditions are transplanted .9 x .9 m apart in a uniform well prepared seed bed with a new transplanting tool that insures uniform depth and establishment (2). Green forage yields are taken at a uniform height either with a sickle bar mower or a riding rotary mower. Four men with the rotary mower, a cylindrical grass catcher made from hardware cloth on a long handle, a dial milk scale and a hardware cloth weighing pan can cut and weigh 1,000 plants in less than 8 hours.

After two seasons of assessment, the five top yielding plants in each 5 x 5 plant block are selected and tagged with red merchandising tags identifying their location. Beginning at 8 a.m., two culms with heads that will start flowering the next day are pulled to include some stolon from each tagged plant; these are tagged together and put in water. Culms from all 200 selections are placed in containers of water (plastic gallon milk jugs with the top cut out but handle attached) and are grouped together on a laboratory table with a north window exposure. A large bag made from kraft wrapping paper to enclose the culms in the 12 milk jugs is suspended from the ceiling and left open at the bottom. Each morning as anthesis is in full sway, the bag covering the heads is squeezed and opened rapidly to insure complete intermixing of the pollen shed from the 200 selections. After anthesis is completed on all heads, the bag is removed and the culms mature their crossed seed without

further treatment.

Mature heads from each selection are threshed separately. In December when the next cycle is started, seeds of each selection are planted in a single 45 cm row with 5 cm between rows in 45 x 60 cm flats of uniformly fertilized steam-sterilized soil at rates to give about 100 seedlings per selection. When about a month old, the seedlings in each row are pulled, the five most vigorous seedlings are transplanted to 5-cm clay pots and the remainder are discarded. By combining seedling selection with field selection, it is possible to screen the 19,900 recombinant plant population necessary to allow the equivalent of one single chance recombination between each of the 200 selected clones. There is increasing evidence that the five top yielding plants in each 5 x 5 block could be selected by visual rating about as well as by actual weight.

We have used a 2-year cycle and have saved 20% of the best plants. Our Pensacola bahiagrass study suggests that we might double the rate of yield increase by using a 1-year cycle and saving three or four rather than five of the best plants in each 25-plant block. To do this would not allow us to screen as well for winter injury or reactions that cannot be assessed in one growing season. The following procedure, however, allowed us to make progress breeding for winter hardiness with a 1-year cycle in 1975. In April, 1976, we set plants .6 x .6 m apart to save land. The plants grew well but failed to produce enough heads at one time in the summer to make the laboratory polycross. Therefore, we will be unable to complete the 1976 cycle until 1977 and it will become a 2-year cycle.

The field number is kept with each 5-plant progeny until we are ready to set the population in the field — usually late April. By this time we will have additional information including a winter hardiness rating on the parent plants. If the parent of a 5-plant progeny fails to survive the winter, we can eliminate its 5 plants from the population to be set in the field. The paternal influence of these plants will remain in the population but by eliminating their maternal influence, we will improve the hardiness of the remaining population more than if they had been left in it. With this procedure, we can also eliminate the progeny of plants that performed poorly after the selections were put together in the polycross. The five seedlings of each remaining selection are thoroughly randomized before they are set in the field for final evaluation.

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IDENTIFYING VIRUS RESISTANCE IN WHITE CLOVER BY APPLYING STRONG SELECTION PRESSURE. I. TECHNOLOGY

By O. W. Barnett and P. B. Gibson

Virus diseases of clovers have been recognized for many years. A mosaic of red clover was reported by Elliot in 1921 (5). Virus diseases of white clover (Trifolium repens L.) were described as early as 1935 by Zaumeyer and Wade (18) and by Pierce (14). By 1949, a virus disease of ladino white clover occurred extensively in the northeastern United States (10). It was soon realized that viruses could severely reduce forage and seed yields of white clover (8, 9). The several viruses that infect white clover may be important in the failure of white clover stands to persist in pastures of the southeastern United States (11).

It is difficult to give a detailed description of all the technology needed when approaching a task such as finding virus resistance in white clover. Some topics which are less familiar will be dealt with in more detail than others. This paper will also deal primarily with white clover but the principles could be used with many other crops.

VIRUSES THAT INFECT WHITE CLOVER

As previously stated, several viruses occur in white clover. Indeed multiple infections of two or three viruses are commonly found in naturally infected white clover. The following 13 viruses have been found in white clover: aphid transmitted - alfalfa mosaic (AMV), clover yellow vein (CYVV), pea streak, peanut stunt (PSV), and red clover vein mosaic viruses; nematode transmitted - Arabis mosaic, strawberry latent ringspot, tobacco ringspot (TRSV), and tomato black ring viruses; thrip transmitted - tomato spotted wilt virus; no known vectors - clover yellow mosaic, tobacco streak, and white clover mosaic (WCMV) viruses (1, 13).

Identification of these viruses requires that several techniques be used because no single technique provides positive identification. As a minimum, host range and host reactions plus serology and/or particle morphology should be used. However, after the viruses found in a particular plant species from a given locality have been identified, a single technique is usually sufficient.

CHOOSING VIRUSES FOR CONCENTRATED EFFORT

Obviously, a breeding program cannot work simultaneously with all 13 viruses. First, find out which viruses occur in your area, state, or region. For example, Lucas and Harper (11) isolated AMV, CYVV, PSV, WCMV, and TRSV from white clover in North Carolina. In the clover plots at Clemson, South Carolina CYVV and PSV are predominant with an occasional plant infected with AMV.

The next step in choosing viruses is to determine which of the viruses present are most prevalent. This can be done two ways. In established clover pastures the viruses should occur at random (1). These pastures can be sampled by collecting clover stolons at intervals diagonally across the pasture without regard for virus symptoms in the stolons. Another method of sampling for virus prevalence tells not only which viruses are most prevalent but also which viruses are transmitted most readily in the area. This method requires a newly established clover plot or pasture. Again samples should be taken at random without regard for symptoms, but more samples will be required to find low levels of infection. If the clover is sampled several times at intervals a more complete picture of virus spread and prevalence can be obtained.

The white clover plants collected by our survey of several southern states, conducted by the first method described, contained AMV, CYVV, PSV, and WCMV (1). Based on the total number of plants collected PSV was the most prevalent virus followed in order by CYVV, AMV, and WCMV. However, if prevalence is based on the number of pastures surveyed CYVV and PSV were about equal in prevalence followed in order by AMV and WCMV.

Another consideration in choosing viruses is the region for which the final virus-resistant variety should be adapted. In the Southeast, white clover is widely used by North Carolina farmers. The major virus in North Carolina pastures was AMV and North Carolina also had more AMV in white clover than other southern states (1). A white clover variety developed for the Southeast should have resistance to AMV if it is to be accepted in North Carolina.

The final consideration to be discussed in choosing viruses is what effect the viruses have on the species concerned. Very little research has been done comparing the effects of different viruses on clover yield. We noted that double infections of PSV and CYVV were associated more with ladino clover plants with low forage ratings (Table 1). However, more of the plants were infected with PSV than with CYVV.

Therefore, we chose to screen for resistance to PSV, CYVV, and AMV. Initial concentration on PSV was proposed because of its widespread occurrence.

VIRUS TECHNIQUES FOR SCREENING PROGRAMS

Identifying virus resistance in a species such as white clover necessitates the use of methods that permit the screening of many plants. The screening involves two main steps, 1) inoculating plants with the virus in a way to avoid escapes or to minimize escapes and 2) assaying or identifying infected plants including those that do not develop symptoms.

Inoculation Techniques

The inoculation procedures will be discussed in detail in the next paper. Briefly, each clover plant is mechanically inoculated four times, the uninfected plants are inoculated by two species of aphid vectors, and then the surviving plants are exposed to natural infection under field conditions.

White clover presents a special problem where mechanical inoculation is concerned because all of the susceptible plants are not infected by a single inoculation. We decided to inoculate four times in order to infect as many susceptible plants as possible. As shown in Table 2 accessions with high susceptibility were almost all infected by this inoculation procedure, while very few plants were infected in other accessions. After field exposure there is a

trend for relatively more uninfected plants from the accessions with more plants surviving mechanical inoculation than from the accessions with few plants surviving mechanical inoculation.

Greenhouse aphid inoculations involve a great deal of work but they approach field conditions more closely. Two sources of techniques for handling aphids and using them as vectors are Aphid Technology by H. F. van Emden (16) and Transmission of Plant Viruses by Aphids by M. A. Watson (17). In our program Myzus persicae (Sulz.) and Aphis craccivora (Koch.) colonies are maintained in cages on Tendergreen mustard spinach (Brassica perviridia Bailey), and Chenopodium quinoa Willd., respectively. The cages are illuminated with fluorescent and incandescent lights for a 19-hour photoperiod. Large numbers of aphids are brushed into plastic tubes and starved for 1 or 2 hours. Then about 100 aphids are placed on the top of an excised infected leaf for 3 or 4 minutes. Only the aphids which crawl to the under surface of the leaf and probe are used. About 10 aphids of each species are then placed on each plant to be inoculated. After several hours the plants are sprayed with malathion to kill the aphids.

Field exposure is the last step in the inoculation procedure. We find that field exposure places the greatest inoculation pressure on white clover. There are several reasons for not using field exposure alone in the screening process although it can be effective if used in conjunction with proper assay procedures. Intensive greenhouse screening by mechanical and aphid inoculations allows for initial screening with individual, known viruses. This makes assay easier because a single plant species can be used for detection since no identification is necessary, yet resistance to each virus can be determined in each plant. Greenhouse screening also allows large numbers of seedlings to be screened and keeps the number of plants in the field small.

The relative effectiveness of the three inoculation procedures is given in Table 3. The 104 plants used represent two vegetative cuttings from each of 52 clones inoculated by each method. In this way the inoculation techniques were compared on the same genotypes. The number of plants infected when the inoculation procedures are used sequentially will be discussed in the next paper.

Assay Techniques

Assay of plants inoculated with single viruses in the greenhouse requires only detection and not identification. Detection of virus infection only by the symptoms which develop on white clover misses many infected plants. When cowpea was used to detect PSV infection, mechanical inoculation of plants from 31 accessions resulted in 545 infected plants. Only 234 (43%) of these infected white clover plants had virus symptoms. Cowpea (Vigna unguiculata (L.) Walp. subsp. unguiculata) is a good assay plant for PSV. Three to four plants can be grown in 2-3 inch pots for inoculation in about 10 days. Symptoms develop locally on the inoculated primary leaf in about 4 to 5 days but the final reading of symptoms should await distinctive systemic chlorotic vein banding as the trifoliate leaves unfold. Chenopodium amaranticolor Coste & Reyn. develops necrotic local lesions sometimes followed by systemic chlorotic vein banding when inoculated with CYVV. Bountiful bean (Phaseolus vulgaris L.) develops necrotic local lesions when inoculated with AMV. When PSV and CYVV both infect white clover, such as occurs in field inoculations, we use both cowpea and C. amaranticolor. Cowpea is not susceptible to most strains of CYVV. On C. amaranticolor the necrotic local lesions caused by CYVV stand out

against the chlorotic local lesions of PSV; no systemic infection of C. amaranticolor occurs as a result of PSV infection.

As mentioned earlier initial identification of the viruses found under different field conditions should be done with techniques to supplement the host range and reactions. The above assay procedures work under South Carolina conditions but variations may occur under other environmental conditions.

VIRUS STRAINS AS THEY AFFECT RESISTANCE SCREENING

Viruses mutate like other living material. Different viruses vary widely in their apparent mutation rate (12). As a result, many strains of some viruses, such as tobacco mosaic virus, have been characterized, but few strains of some other viruses, such as tomato bushy stunt virus, have been found.

Plants resistant to one strain of a virus may not be resistant to other strains. Diachun's work with bean yellow mosaic virus (BYMV) resistance in red clover typifies this problem (3). Four strains of BYMV produced almost every combination of mosaic, necrosis or no symptoms on 55 red clover clones. Thus some clones exhibited only mosaic symptoms when inoculated with any of the four strains, other clones exhibited no symptoms with any of the strains, and other clones exhibited different reactions to the different strains. The predominant strain of BYMV in Kentucky red clover remained the same over the last several years (4, 7), but this is not true for all viruses. For example, the predominant barley yellow dwarf virus strain can change over a period of several years in a locality, and in different localities in the same year the predominant strains can be different (15). Little work on strain separation has been done with AMV, CYVV, and PSV from clovers. J. P. Meiners (personal communication) has found different reactions of bean varieties to several isolates of PSV. L. T. Lucas (personal communication) found an isolate of CYVV that produced systemic symptoms in cowpea. The problem of virus strains in the forage legumes still needs to be studied. That strains of the major forage viruses occur is beyond question, but their effect on a breeding program is unanswered except in the case of BYMV on red clover in central Kentucky.

NATURE OF VIRUS RESISTANCE

Very little research has been done on the nature of virus resistance in the clovers. Several types of resistance that have been found are discussed below.

Resistance to BYMV in red clover is exhibited as a localized, hypersensitive reaction (4).

A single source of resistance to CYVV in white clover has been studied. This plant 1) was susceptible to CYVV only by repeated mechanical inoculation, 2) had a very low virus concentration when infected, and 3) had field resistance. This apparently is a multigenic type of resistance or tolerance.

A single source of resistance in white clover to PSV has also been studied. The resistant plant has not been infected yet. When this plant was crossed with a susceptible plant the progeny were mostly resistant to PSV (24 resistant of 38 plants). The S_1 selfed generation segregated into several resistance classes as shown in Table 4. These preliminary data suggest the presence of a dominant and a recessive gene controlling the resistance.

From this discussion it is apparent that various types of virus resistance exist in clovers. This obviously complicates the production of varieties with resistance to several viruses.

CONTROL OF VIRUS DISEASES

Several methods of controlling virus diseases have been devised. Most of these are more appropriate for other types of crops than forage legume, however.

Removal of sources of infection can be of some help with new plantings of forage legumes. Following this practice, new plantings would be started away from other pastures. Usually, however, the forage legumes serve as sources of viruses for other crops.

Virus-free seed or vegetative stocks would appear to be of minor importance also. However, certain viruses are seed transmitted in red clover, although in low percentages (6). Virus-free vegetative stocks have also proved useful in breeder seed production where vegetatively propagated clones are required (2).

Modified planting and harvesting procedures can be used with some crops. Some annual crops can be planted after major aphid flights to escape infection, or they can be planted early and harvested before the virus infection reduces yield. These procedures probably cannot be adapted for forage crops.

The use of reflective surfaces and oil sprays are new methods for controlling virus diseases. For the reflective surface procedure to be effective, about 50% of the ground surface needs to be covered. This would not be possible with forage crops. Oil sprays have been used to prevent virus spread, but are usually only effective in delaying infection. They would be too expensive for forage crops and would only delay infection several months if used.

Control of vectors by chemical sprays has been used effectively with some viruses but not with the nonpersistent, aphid-transmitted viruses such as AMV, CYVV, and PSV.

For control of virus diseases of forage legumes, the best or perhaps the only control is breeding immune, resistant, or tolerant varieties either to the virus or against the vector. Some projects, such as those at Kentucky and North Carolina, have already shown that it is possible to incorporate resistance to virus diseases into forage legumes. The next report also indicates that selection of virus-resistant clones is possible. Perhaps someday we will have virus-resistant varieties.

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TABLE 1.--Relation of forage ratings to virus infection in ladino clover

Forage rating[a]	No. virus-infected plants[b]			
	PSV	CYVV	Both	Total
0-5	22	13	12	23
6-10	9	6	6	9
Total	31	19	18	32

[a]Forage rating is from 0, plant dead, to 10, best forage rating. Some factors considered in the forage rating of 32 individual spaced plants included vigor, ground cover, and forage density.

[b]PSV = peanut stunt virus, CYVV = clover yellow vein virus, Both = plants infected with both PSV and CYVV.

TABLE 2.--Effectiveness of mechanical inoculation of white clover accessions with peanut stunt virus

Accession	No. plants inoculated	Plants not infected (%)
2682	56	2
3756	60	10
4249	50	14
4753	50	12
FC 40874	155	69
PI 4-2080-3	50	76
PI 234678	64	89
4804	54	62

TABLE 3.--Comparison of mechanical, aphid, and field inoculation of white clover genotypes with clover yellow vein virus

No. genotypes inoculated	Inoculation method		
	Mechanical (%)[a]	Aphid (%)	Field (%)
52	46	54	85

[a]Percent plants infected of two vegetative propagules of each of the 52 genotypes for each inoculation method.

TABLE 4.--Incidence of peanut stunt virus (PSV) resistant plants in S_1 families from F_1 crosses of a PSV resistant x PSV susceptible

Resistance class (%)	No. families	No. plants resistant/ No. plants inoculated
98-100	4	173/175
91-93	2	81/88
81-88	3	115/135
46-51	2	46/95

IDENTIFYING VIRUS RESISTANCE IN WHITE CLOVER BY APPLYING STRONG SELECTION PRESSURE. II. SCREENING PROGRAM

By P. B. Gibson and O. W. Barnett

Obviously, time does not permit a detailed discussion of all the logical subtopics of my assignment. I will barely mention some topics and will discuss others in more detail. The rationale for this approach is that a detailed discussion would involve considerable information that has been presented elsewhere and is common knowledge to forage breeders. This discussion is more or less limited to white clover; however, with modification it applies to other species.

JUSTIFICATION FOR SCREENING PROGRAM

We believe the virus diseases collectively comprise the most important problem in white clover production. This belief is based on observations, circumstantial evidence, and data.

Unfortunately, definitive field data as would be supplied by paired plots of virus-free vs. virus-infected are not available. The plots can be established but to date no one has satisfactorily maintained virus-free plots. Positive air flow open end chambers (2), as have been used in air pollution research, may be a way to obtain a statistically valid measurement of the importance of the viruses. I will briefly mention some of our reasons for considering viruses the number one problem:

a) Virus symptoms are common on clover in pastures.
b) Results of surveys of pastures indicate a high incidence of virus diseases on clover (1&4).
c) Longevity of clover in renovated pastures generally is shorter than that of new stands. Usually a few clover plants persist and may serve as a source of the virus to infect new seedlings.
d) Experimental data reported by Kreitlow (3) and later by Barnett and Gibson demonstrate the reduction in yields attributed to viruses under the conditions of the experiments.
e) In space planted nurseries, we have observed a close association between infection with peanut stunt virus and decline of white clover plants.
f) Comparisons of virus-free and virus-infected plants growing in pots in the greenhouse and in growth chambers have demonstrated the detrimental effects of the viruses.

This evidence has convinced us of the importance of viruses. Consequently, we are devoting almost our entire effort to identifying virus resistance.

PERTINENT CHARACTERISTICS OF WHITE CLOVER

In general, the characteristics of white clover facilitate a screening and

breeding program. The following fragmentary statements apply to white clover plants or to the species:

a) Easily propagated vegetatively and easily transplanted.
b) Normally cross-pollinated.
c) Most plants will produce selfed seed, especially at temperatures of about 35°C.
d) Hand-pollinations are not difficult to make.
e) Meeting the greenhouse requirements for growing, bringing into flower and seed production is relatively easy.
f) Is an evolutionary tetraploid, but most inheritance is disomic.
g) Is a perennial, will behave as an annual, and has been hybridized with other perennial and annual Trifolium species.
h) Most plants will flower over a relatively long period and flowering is largely controlled by the photoperiod.
i) Seed in dry-cold storage will remain viable for several years.

THE SCREENING PROGRAM

As an introduction to our discussion of the screening program I emphasize that it is a cooperative Federal-State program. A brief summary of the entire screening process is presented as a preview to help visualize the logic for the individual steps.

Seedling plants are screened in the greenhouse first for resistance to Peanut Stunt Virus (PSV). Susceptible plants are discarded and each surviving plant is vegetatively propagated to provide one plant to screen for resistance to Clover Yellow Vein Virus (CYVV), one plant to screen for resistance to Alfalfa Mosaic Virus (AMV), and one plant to be transplanted into the field where it is exposed to the natural array of vectors and viruses.

Preparing Plants for Screening

Seed are planted in methyl bromide-fumigated soil, inoculated with rhizobia bacteria by watering with a slurry suspension of peat containing the bacteria or inoculated at time of transplanting by dipping roots in the slurry. The resulting seedlings are grown to about the second trifoliate leaf stage.

About 50 to 100 seedlings of each source are transplanted individually into 4-inch pots. The intention is to screen 50 seedlings of narrow genetic base sources and 100 seedlings of broad genetic base sources such as mass-selected varieties.

Screening for Resistance to PSV in Greenhouse

Screening for Resistance to PSV by Mechanical Inoculations. When seedlings attain the 5 to 10 leaf stage (about 4 to 6 weeks) they are mechanically inoculated (abrasive smear technique) with PSV. The inoculation is repeated weekly or at shorter intervals, for a total of four inoculations. Two weeks after the fourth inoculation, all plants with visual symptoms are discarded. On the remaining plants, stolons that extend over the rim of pots are pruned and the leaves are trimmed at a height of about one inch. One week later, the plants are assayed onto Vigna unguiculata (L.) Walp. cv. Blackeye cowpea seedlings using young clover leaves as the source of inoculum. The initial reading of the assay cowpea plants is made 7 days after inoculation and the final

reading is made on the tenth day. All infected clover plants, as indicated by the responses on the cowpea seedlings, are discarded. The remaining clover plants are considered to be resistant to PSV by mechanical inoculation and are again pruned in preparation for inoculation by vector aphids.

Screening for Resistance to PSV by Viruliferous Aphids (5&6). One week after pruning, the plants are moved to an isolated section of the greenhouse and 10 viruliferous (PSV) Myzus persicae are placed on each plant. About one hour later, 10 viruliferous (PSV) Aphis craccivora are placed on each plant. After the plants have been exposed to the latter species of aphids for 1 hour or longer, the plants are treated with an appropriate pesticide to eliminate the aphids and are returned to the growing area of the greenhouse. Two weeks after exposure to aphids, the plants are pruned and 1 week later new growth is used as the source of inoculum to assay onto cowpea seedlings as was done after the mechanical inoculations. Again, all infected clover plants are discarded.

Vegetative Propagation

Each surviving plant is propagated vegetatively to provide one plant of each genotype to screen for resistance to CYVV, one to screen for resistance to AMV, one to transplant into the field, and one to hold in the greenhouse.

Screening for Resistance to CYVV

Clover plants are screened for resistance to CYVV by the same procedure used to screen for PSV resistance, with the exception that plants of Chenopodium amaranticolor Coste & Reyn. are used in lieu of cowpeas to assay for infected plants.

Screening for Resistance to AMV

Clover plants are screened for resistance to AMV by the same procedure used to screen for PSV resistance, with the exception that plants of Phaseolus vulgaris L. cv. Bountiful are used in lieu of cowpeas to assay for infected plants.

Field Screening

Rooted cuttings of the plants surviving the greenhouse screening for resistance to PSV are transplanted into a field. Past experience indicates that the requirements to effect a high incidence of infection with PSV and CYVV are present in this field. AMV infection occurs but at a lower incidence. Clover plants that survive the greenhouse screening and remain virus-free for 1 year or longer in this field are considered to possess some degree of resistance.

Additional Comments

The program is designed to identify resistance as much as possible while the plants are young and growing in small containers. Although we are seeking multiple resistance, i.e., resistance to PSV, CYVV, and AMV, the program identifies resistance to individual viruses.

The program will be modified as experience dictates. Preliminary results indicate that resistance to mechanical inoculation, variation in vector

preference, virus strains, levels of tolerance in clover, variation in symptom expression, variation in susceptibility with age, and environmental effects all must be considered.

We are exposing the plants to the viruses by using more than one method of inoculation in an effort to eliminate the chance of selecting for resistance to a virus by a specific method of inoculation and not resistance to the virus.

At the present time, clover plants considered undesirable because of size, type of growth or other agronomic reasons are discarded. Preliminary results indicate that the greenhouse screening, after discarding virus-infected plants and agronomically undesirable plants, will supply all the plants we can classify in the field.

Elite Clones

Plants surviving the above eliminations are considered elite genotypes and will be evaluated further to confirm their value. Advanced evaluations will include test crosses and progeny evaluations to insure that the resistance is transmitted and to determine the inheritance of the resistance.

PRIORITY OF SOURCE MATERIALS FOR SCREENING

We have given top priority to sources such as adapted varieties. A plant selected from such material can be used as is, to be a parent of an improved variety. Sources that require crossing and selecting to transfer resistance to a desirable agronomic line have a lower priority. In general, the materials we are screening and the priorities we have given the materials are:

1st Priority - Progenies from elite clones.
2nd Priority - Adapted varieties.
3rd Priority - Plant Introductions reported to be promising on the basis of preliminary tests.
4th Priority - Any white clover germplasm not included in above priorities.
5th Priority - Species hybrids.

The species hybrid of T. ambiguum Bieb. and T. repens L. probably offers the best resistance available. We placed it last because 1) the hybrid has to be made and 2) crossing and selecting to combine resistance, desirable agronomic characters, and stability may require considerable time.

PROGRESS

Approximately 4,000 seedlings have been fed into the program. New seedlings are constantly started and plants are in all steps of the program. The percentage of plants that survive the inoculations varies from source-to-source. We interpret this variation to be an indication that levels of resistance exist within the species.

A few plants from the early days of the program survived and were exposed in the field during the summer of 1976. Some of these plants remained virus-free and open-pollinated seed were harvested. Preliminary data from seedlings grown from the seed indicate that we are making progress.

Since we have completed the screening program on relatively few sources, my examples will largely be limited to results from mechanical inoculations. The percentage of survivors may seem to be high but remember that inoculations with aphids and field exposure also eliminate plants. Our best estimate at present is that, on the average, about six plants out of 100 fed into the

TABLE 1.--Virus-free white clover plants at successive steps in the screening program

Category	No. plants	%
Total plants from 17 accessions	1036	100
Plants not infected with PSV after:		
Mechanical inoculations	431	42
Aphid inoculations	314	30
Field exposure (one season)	94	9
Plants free of PSV, CYVV and AMV after one season in field	63	6

TABLE 2.--Percent of white clover plants free of PSV after four mechanical inoculations.

Source	% PSV free
Varieties:	
California Ladino	76
Green Acres	17
Louisiana S-1	46
Merit	30
Pilgrim	31
Tillman	46
Germplasm lines:	
PI 388632	16
PI 234678-a	74
PI 239976	83
PI 234678-b	89
FC 40874	69
O.P. Progenies from clones:	
2682	2
4249	14
4736	54
4758	30
4804	34
O.P. Progenies from selected clones (2nd cycle):	
1-40 (PSV infected in field)	35
4-44 (PSV infected in field)	29
1-93 (PSV free in field)	97
3-36 (PSV free in field)	90

program will reach the field and survive virus-free through the first growing season. In the case of some sources, no plants survived.

Selected examples of results from our screening program are presented in Tables 1 and 2. These are representative samples, but obviously, comparisons are not statistically valid since screening of the various sources was not randomized, replicated and conducted simultaneously.

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THE APPLICATION OF THE COEFFICIENT OF INBREEDING TO FORAGE BREEDING METHODS

By Thad H. Busbice

Inbreeding is the mating of relatives. The more related the parents, the more inbred will be the offspring. In plants the most extreme form of inbreeding is selfing, followed by backcrossing of offspring to parent and sib mating. These forms of inbreeding are easy to recognize, but it is also important to recognize that some inbreeding occurs even when the parents are only remotely related.

Inbreeding can be defined by two genetic parameters:

(1) The coefficient of parentage--the probability that a random gene at a locus from one parent is identical to a random gene from that locus in the other parent.

(2) The coefficient of inbreeding--the probability that two genes picked at random from a locus are identical by descent.

It follows that the coefficient of inbreeding is computed from a knowledge of the coefficient of parentage. Wright (1921), Malecot (1948) and Kempthorne (1957) have contributed to this concept.

To have meaning, the coefficient of inbreeding must relate to some conceptual noninbred population. It is not necessary that this noninbred population be random-mated or to be in equilibrium. It is necessary only that it is conceptually defined, and that comparisons of inbreeding coefficients be confined to that conceptual framework. Only individuals are inbred, but a family of such individuals is said to be an inbred family. Also, any population that contains inbred individuals is considered to be an inbred or partly inbred population. The coefficient of inbreeding of a population is the average of the coefficients of inbreeding of the individuals that make up the population. Thus, a forage variety is said to be partly inbred when any of its plants are inbred or partly inbred. Most inbreeding computations can be resolved from the coefficients of parentage of four mating designs:

SELFING

$r_{xx} = \frac{1}{2k} [1 + (2k - 1) F_x]$ = the coefficient of parentage of individual x with itself.

BACKCROSSING

$r_{x(xy)} = \frac{1}{4k} + \frac{2k-1}{4k} F_x + \frac{1}{2} r_{xy}$ = the coefficient of parentage of parent x with its offspring xy (from the mating of parent x with parent y).

FULL SIB-MATING

$r_{(xy)(xy)} = \frac{1}{8k} [2 + (2k-1) (F_x + F_y) + 4kr_{xy}]$ = the coefficient of parentage of individual xy (from the mating of parents x and y) with its full sib.

HALF SIB-MATING

$r_{(xy)(yz)} = \frac{1}{8k} [1 + (2k-1) F_y + 2k (r_{xy} + r_{xz} + r_{yz})]$ = coefficient of parentage of individual xy (from the mating of parents x and y) with its half-sib yz (from the matings of parents y and z).

Where: F_x and F_y are the coefficients of inbreeding of parents x and y; r_{xy}, r_{xz}, and r_{yz} are the coefficients of parentage of parents x, y, and z; and k is one-half the ploidy number (i.e., 1 for diploids, 2 for autotetraploids, etc.). The coefficient of inbreeding of any individual ij from mating parents i and j is

$$F_{ij} = \frac{1}{2k-1} [k\ r_{ij} + \frac{k-1}{2} (F_i + F_j)]$$

It is necessary to define the degree of inbreeding and relationship in the parents from which the degree of inbreeding can be computed in the offspring.

The degree of inbreeding in a random mating population, such as synthetic varieties, can be computed easily from existing formulae. (See Busbice, 1969). Because many forage varieties are propagated as synthetic varieties, certain relationships about synthetic varieties are important to know:

(1) $r_1 = \frac{1}{n} [\frac{1 + (2k-1)F_o}{2k}] + [\frac{n-1}{n}] r_o$ = the average coefficient of parentage among individuals in advanced generations.

Where: n = the number of parents

r_o = the average coefficient of parentage among the parents.

F_o = the average coefficient of inbreeding of the parents.

When the parents are noninbred and unrelated $r_1 = \frac{1}{2kn}$

(2) $F_e = r_1 + [s\ (1-r_1)]\ /\ [s + 2k\ (1-s)]$ = the coefficient of inbreeding at equilibrium.

Where: s = the frequency of selfing

When s equals zero, $F_e = r_1$.

(3) $D = \frac{k}{2k-1} - \frac{s}{2}$ = the distance traveled toward equilibrium with each generation of random mating following the first generation.

When the population is diploid and no selfing occurs, equilibrium is reached in one generation past the Syn 1, that is, in the Syn 2. In polyploids, equilibrium is reached asymptotically, but nevertheless rapidly, with generations of random mating. In autotetraploid varieties multiplied without selfing 2/3 the distance to equilibrium is covered with each generation. Selfing increases inbreeding and slows the approach to equilibrium.

Why be concerned about the coefficient of inbreeding? All naturally outcrossing forage species (alfalfa, crownvetch, clover, orchardgrass, and many others) are subject to severe inbreeding depression of forage and seed yield, and some depression may occur even when the degree of inbreeding is small.

TREADMILL EFFECT OF RECURRENT SELECTION

Recurrent selection is a mild form of inbreeding in that each cycle is started from a finite population. The fewer parents used to initiate each cycle, the greater will be the risk of serious inbreeding, and inbreeding will increase with each generation of selection.

A population created by recurrent selection may have great plant to plant variation, yet fail to respond to continued selection pressure. Although exceptional parents are selected, the progeny may not exceed the previous cycle in performance. The reason is that a threshold level of inbreeding has been reached that offsets any advantage possible from selection. The answer is in the coefficient of inbreeding:

$$F_{ij} = \frac{1}{2k-1} [k\ r_{ij} + \frac{k-1}{2} (F_i + F_j)]$$

While the parents may be exceptional and possibly noninbred, they can be related ($r_{ij} \neq 0$) and the resulting progeny partly inbred ($F_{ij} \neq 0$).

Therefore, one cannot be assured of continued success from recurrent

selection just because a great amount of genotypic variation remains in a population.

GENOTYPIC VARIATION

An intermating population contains a mixture of mating designs, i.e., full and half sib-matings and possibly selfing, outcrossing, and the mating of cousins. Therefore, all individuals issuing from an intermating population will not have the same degree of inbreeding or show the same level of inbreeding depression. Thus, the genotypic variance of an intermating population, such as those used in recurrent selection programs, may be exaggerated by inbreeding.

On the other hand, deliberate inbreeding will sometimes produce surprising uniformity in the progeny. For example, selfing a noninbred plant will produce an S_1 family, each member of the family being full sibs of the other members, and each having the same degree of inbreeding. In addition, in autopolyploids restricted segregation occurs because of the polyploid gamete. While one might normally expect wide segregation in an S_1 family, variation for some characters may be less than such variation in intermating populations.

RESIDUAL INBREEDING

In autopolyploids, such as alfalfa, an individual will be inbred to a degree if its parents were inbred. This is obvious from the inbreeding formula:

$$F_{ij} = \frac{1}{2k-1} \left[k\, r_{ij} + \frac{k-1}{2} (F_i + F_j)\right]$$

Even though the parents are totally unrelated ($r_{ij} = 0$), a residual of inbreeding will be passed from the parents to the offspring through the gametes. In autotetraploids the offspring will contain 1/3 of the average inbreeding of the parents.

DELAYED INBREEDING OR TIME BOMB EFFECT

Synthetic varieties produced without selfing from diploid parents will stabilize in the Syn 2 generation. However, in autopolyploids equilibrium is reached asymptotically and a snythetic variety will not stabilize until the fourth or more advanced generations. Synthetic varieties produced from noninbred parents will become increasingly more inbred with each generation until equilibrium is reached, the amount of inbreeding being inversely related to the number of parents used to start the variety. Thus, a variety that performs exceptionally well when tested in the Syn 1 and Syn 2 generations may perform disappointingly in advanced generations when it reaches the farmer because of inbreeding depression. Such depression will likely surface first in reduced seed production.

PREDICTING YIELD

In heterotic species, such as most forage species, there is a systematic relationship between the coefficient of inbreeding and yield. This relationship may be linear or exponential, but once it has been determined, the relationship can be used to predict the performance of partly inbred populations. One such relationship (presented by Busbice and Gurgis, 1976) is:

$$Y_e = Y_1 - [(2k-1)(Y_1 - S_{1avg.})/kn]$$

Where Y_e = the equilibrium yield of a synthetic variety

Y_1 = the Syn 1 yield, or the average of the single crosses among the parents.

$S_{1avg.}$ = the average self yields of the parents.

Again k is one-half the ploidy, and n is the number of parents.

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CHARACTERIZATION OF FORAGE TISSUE BY TRANSMISSION AND SCANNING ELECTRON MICROSCOPY

by Danny E. Akin, E. L. Robinson, and Donald Burdick

We have used both transmission and scanning electron microscopy (TEM and SEM, respectively) to confirm and expand observations of forages by light microscopy, but the most important use has been to study the relative rates and extents of rumen microbial digestion of different forage tissues in their structurally intact state. In order to fully understand these investigations, one should realize the basic advantage of each type of microscope. Table 1 shows a comparison of the magnification and resolution of the light, transmission electron, and scanning electron microscopes. Transmission electron microscopy provides the greatest resolution while a large depth of field is available with scanning electron microscopy.

TISSUE CHARACTERIZATION

Patterns of tissue organization, relative cell wall thickness, and cell wall rigidity are easily seen by SEM and can complement light and histochemical observations (Akin and Burdick, 1973). A cross-section of a Coastal bermudagrass (CBG) leaf blade observed by SEM is shown in Figure 1. CBG blades had closely spaced vascular bundles surrounded by well-developed parenchyma bundle sheaths which is typical for warm-season grasses (Brown, 1958; Downton and Tregunna, 1968). CBG had a high percentage of vascular bundles in leaf blades (Akin and Burdick, 1975). The more loosely arranged and thin-walled mesophyll cells, which comprised a lower percent of blade area than in cool-season species (Akin and Burdick, 1975), occupied the area between bundles. The epidermal cells were thick-walled compared to the mesophyll. Thickened, rigid walls of lignified cells (as determined histochemically) comprised the sclerenchyma and xylem area of the vascular bundles. TEM of a CBG blade (Fig. 2) revealed that the bundle sheath cell wall was laminated (i.e., alternate electron dense and transparent layers) and slightly less than one μm wide. Additionally, the bundle sheath cells contained chloroplasts with large numbers of starch grains, typical for C4 or warm-season grasses; thin-walled mesophyll cells usually lacked starch (Downton and Tregunna, 1968).

SEM of Coastcross-1 bermudagrass (CX-1) leaf blades revealed tissues identical to those in CBG. Histochemical and morphometric studies have confirmed these similarities (Akin and Burdick, 1973; Akin and Burdick, 1975). However, differences in the size of small vascular bundles and arrangement of the bundle sheaths around the large bundles existed in Pensacola bahiagrass (PBG) leaf blades (Fig. 3) as compared to CBG.

Ky-31 tall fescue (Fig. 4), an anatomical representative of the cool-season, festucoid grasses (Brown, 1958), differ even more from CBG with vari-

TABLE 1.--Comparisons of types of microscopes

Type	Resolution (Å)	Magnification
Light Microscope	2000	up to 1,000 to 1,200 x
Transmission Electron Microscope	<10	up to 200,000 x or >
Scanning Electron Microscope	50 to 500	up to 200,000 x
(Provides a Large Depth of Field Giving a Three-Dimensional Image)		

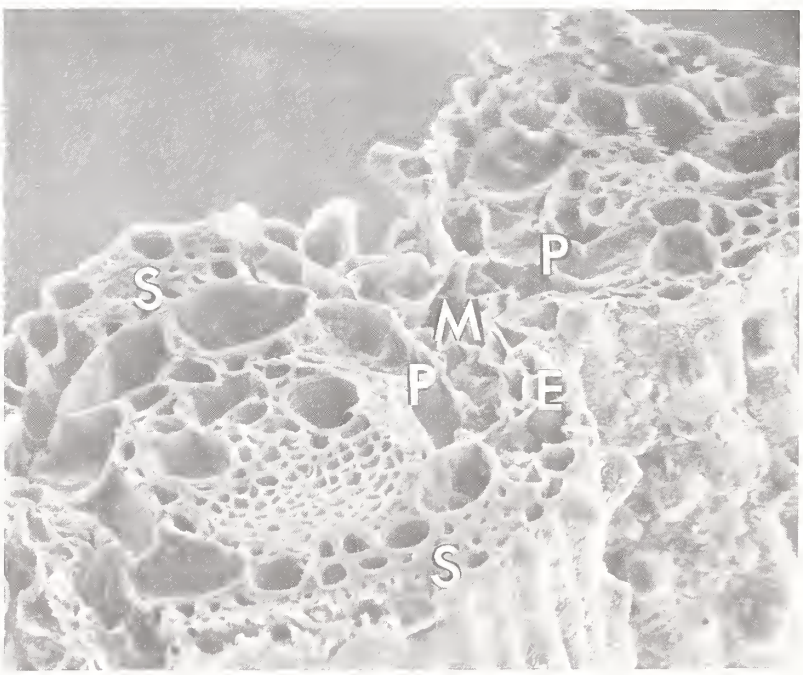

FIGURE 1.--SEM of cross-section of Coastal bermudagrass leaf blade. Vascular bundles are closely spaced and have well developed parenchyma bundle sheaths (P). Mesophyll (M) separates bundles, which are connected to the epidermis (E) by sclerenchyma (S). X629.

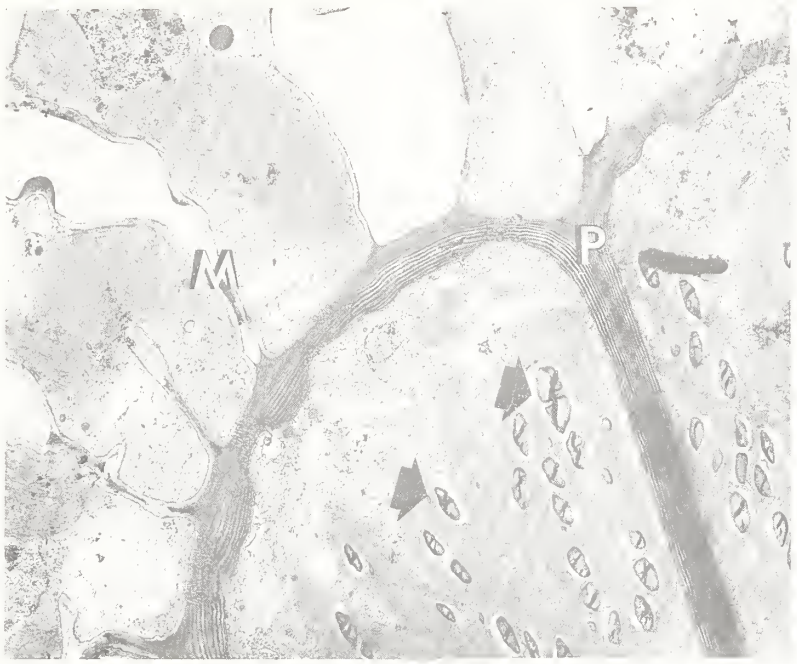

FIGURE 2.--TEM of Coastal bermudagrass leaf blade. Parenchyma bundle sheath cells (P) are closely adjoined and have thick, laminated cell walls; thin-walled mesophyll (M) cells are loosely-arranged. Starch grains (arrows) are numerous in chloroplasts of parenchyma sheath cells; chloroplasts in the mesophyll lack starch. X4,752.

FIGURE 3.--SEM of cross-section of Pensacola bahiagrass leaf blade. Vascular bundles are closely spaced and have well developed parenchyma bundle sheaths (P). Mesophyll (M), epidermis (E), and sclerenchyma (S) are noted. X614.

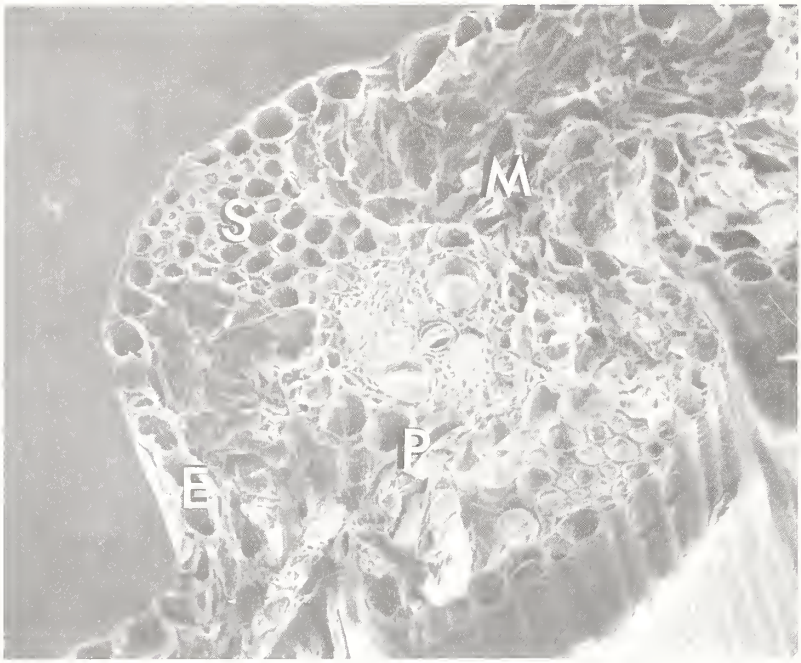

FIGURE 4.--SEM of cross-section of Ky-31 tall fescue leaf blade. Vascular bundles are widely spaced and the parenchyma bundle sheath (P) is not well-developed. Mesophyll (M), epidermis (E), and sclerenchyma (S) are noted. X275.

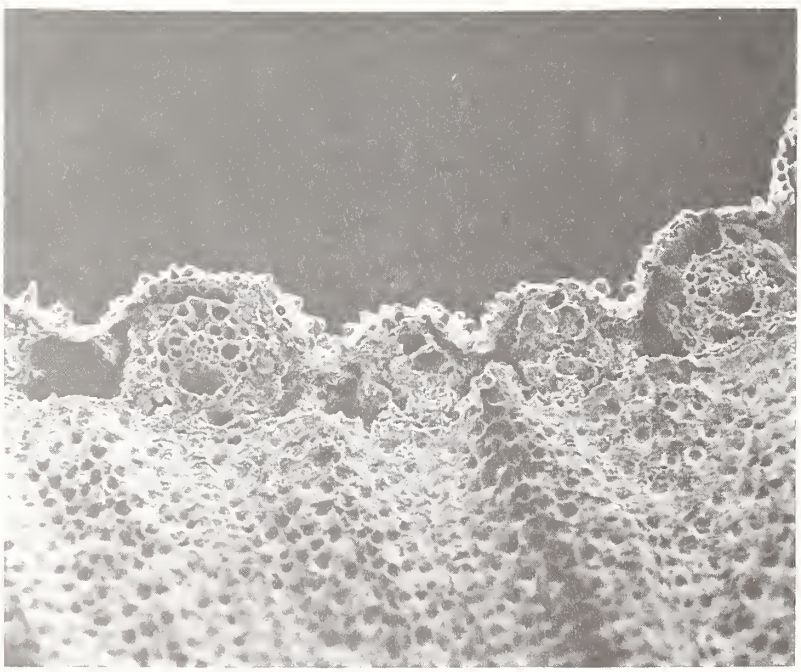

FIGURE 5.--SEM of Coastal bermudagrass blade incubated 12 hours with rumen bacteria. Phloem and mesophyll are degraded, but parenchyma sheath and epidermis are only partially removed; lignified vascular and sclerenchyma cells are intact. X234.

ations in the thickness of the bundle sheath cell wall and in inherent rigidity. Mesophyll tissue usually occupied more leaf blade area than in warm-season grasses (Akin and Burdick, 1975).

CHARACTERIZATION OF TISSUES INCUBATED WITH RUMEN MICROORGANISMS

Leaf Blades. SEM of grasses incubated with rumen microorganisms (in vitro) revealed patterns of specific tissue digestion of intact, unground forages. Cell wall digestion, therefore, could be evaluated for the relative rate and extent of degradation by rumen microorganisms in relation to the structural features of the tissues. The depth of field of SEM permitted examination of tissue digestion from the cut ends of blade sections without serial sectioning and provided greater magnification and resolution vs. that obtained with light microscopy (Table 1). A comparison of leaf blade sections digested for 12 hours with aliquots of the same rumen fluid inoculum revealed differential tissue loss between forage cultivars (cf Fig. 5 with 6), forage species (cf Fig. 5 with 7 with 8), and forage types (cf Fig. 5, 6, 7 with 8). Although differences in the degradation of tissue types existed among forages, a pattern was found in all species examined: mesophyll and phloem were more easily digested than parenchyma sheath and epidermis while sclerenchyma and lignified vascular tissue (i.e., inner bundle sheath, xylem) were essentially indigestible. Identical patterns of tissue degradation have been shown for these and other forage grasses by light microscopy (Regal, 1960; Hanna, Monson, and Burton, 1973). TEM of rumen bacterial interrelationships with forage tissues (Akin, Burdick, and Michaels, 1974) indicated that bacterial attachment to slowly degraded cell walls often occurred (Fig. 9) whereas the rapidly digested tissues were often degraded apparently without bacterial attachment; lignified tissues had few attached bacteria (Fig. 10).

Two factors appear to influence the ease (or relative rate) and extent of blade digestibility and perhaps should be considered in forage breeding programs designed for increasing digestibility. These factors are: i) the amounts of tissue types present, and ii) the inherent cell wall nature of similar tissues among grasses. The first factor is demonstrated in Table 2. The less digestible warm-season grass blades usually had a higher percentage of the more slowly degraded epidermis and parenchyma bundle sheath; conversely, the more digestible cool-season blades consisted of a higher percentage of the easily digested mesophyll and phloem. It would therefore appear worthwhile to select for forages with a higher percentage of mesophyll and phloem to improve digestibility per se. This difference in the 'rate' of digestibility of digestible tissue has been recognized and used to expand equations mathematically describing cell wall digestion (Mertens, 1977). However, the amount of (non-degraded) lignified tissue appeared to limit only the extent of tissue digestion (Akin and Burdick, 1975). The amount of these indigestible tissues were similar between warm-season and cool-season grasses and were lowest in some warm-season species. This limitation of only the extent of tissue digestion by lignin has been suggested by others (Smith, Goering, and Gordon, 1972; Mertens, 1977). Perhaps plant breeding could be useful to increase the rate of digestibility by modifying blade anatomy as has been found in species intermediate between C_4 and C_3 Panicum spp. (Brown and Brown, 1975) and with F_1 hybrids of C_4 and C_3 parents in Atriplex (Björkman, 1976). Of course, potential modifications must be considered in light of the effect on forage yield

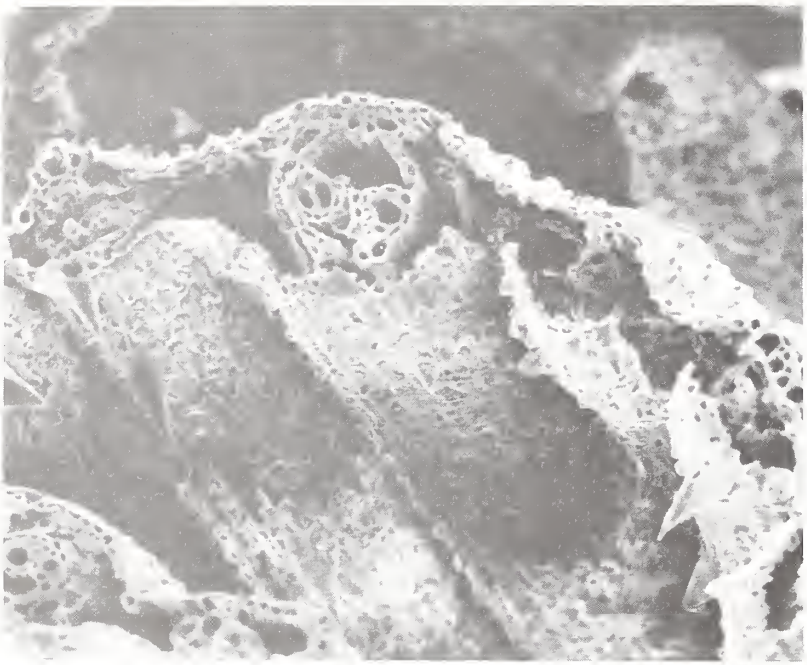

FIGURE 6.--SEM of Coastcross-1 bermudagrass blade incubated 12 hours with rumen bacteria. Phloem, mesophyll, and much of the parenchyma sheaths and epidermis are degraded; lignified tissues are intact. X288.

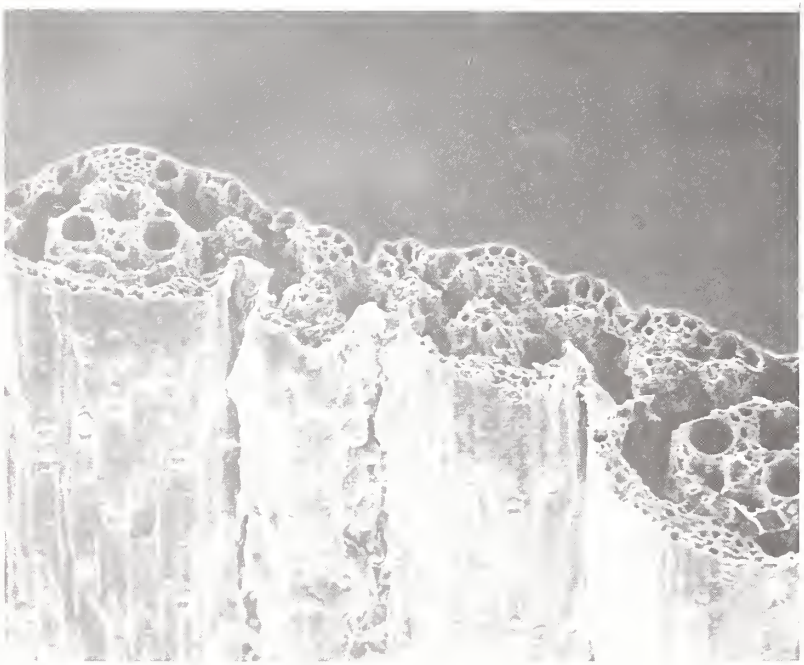

FIGURE 7.--SEM of Pensacola bahiagrass blade incubated 12 hours with rumen bacteria. Phloem and mesophyll are degraded, but epidermis and parenchyma sheaths (of small bundles) are only partially removed; lignified tissues are intact. X288.

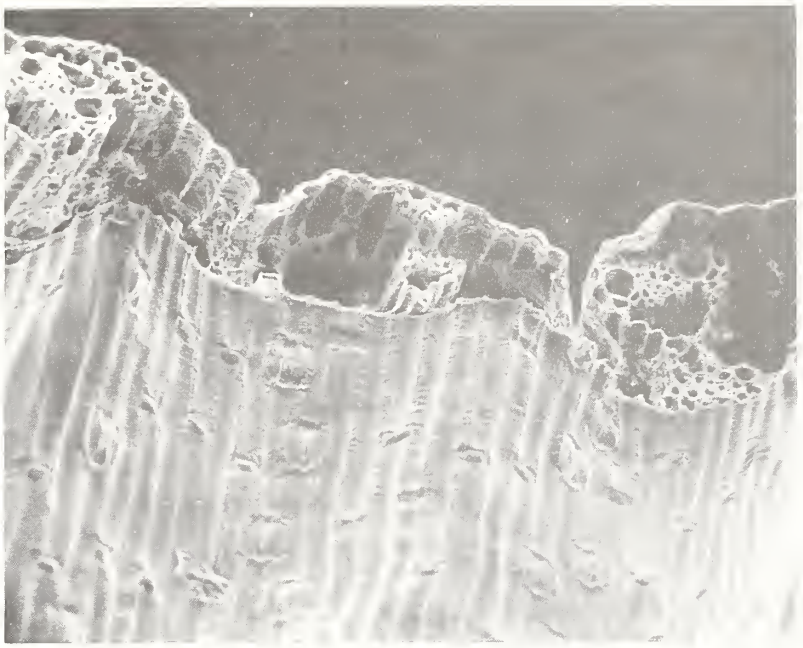

FIGURE 8.--SEM of Ky-31 tall fescue blade incubated for 12 hours with rumen bacteria. Digestible tissues are removed leaving only lignified cells. X252.

FIGURE 9.--TEM of Ky-31 tall fescue bundle sheath cell wall with attached, cellulolytic rumen bacteria. Several types of rumen bacteria (B) adhere closely to the plant wall (W) during degradation. X13,050.

Table 2.--Percent of tissues in leaf blades characterized by ease of digestibility

Grasses	Rapidly Degraded (Phloem & Mesophyll)	Slowly Degraded (Epidermis and parenchyma sheath)	Nondegraded (Lignified vascular and sclerenchyma)
CBG	31.0	54.7	14.3
CX-1	27.2	56.2	16.6
PBG	54.7	36.4	8.9
Dallis	45.9	45.0	9.1
Pangola	33.8	57.9	8.2
Crab	35.6	57.6	6.3
Brome	55.6	25.6	19.0
Orchard	56.0	29.4	15.7
Timothy	56.2	31.4	12.4
Bluegrass	66.0	21.8	12.3
Ky-31	62.0	27.0	11.0
Kenhy	63.8	23.5	12.7

TABLE 3.--Percent degraded parenchyma bundle sheaths in warm-season and cool-season grasses after 12 hours incubation with rumen microorganisms

	Percent Parenchyma Bundle Sheath		
Grass	Undegraded*	Partially Degraded+	Degraded++
CBG	55.8	34.8	9.3
CX-1	25.0	70.8	4.2
PBG	0	13.3	86.7
Dallis	100	0	0
Brome	0	0	100
Orchard	0	3.4	96.6
Bluegrass	0	0	100
Timothy	0	12.5	87.5
Ky-31	14.3	42.9	42.9
Kenhy	0	63.6	36.3

* More than 3/4 of sheath cells undegraded.
\+ At least 1 cell but no more than 3/4 sheath cells undegraded.
++ All sheath cells completely degraded from the depth of focus of the microscope.

which also appears to be related to the anatomy and physiology of warm-season plants (Downton and Tregunna, 1968; Black et al., 1971; Björkman, 1976).

In regard to the second factor (i.e., inherent cell wall nature), SEM has shown variations in the ease of digestibility of anatomically similar tissues among various forages (Fig. 5 and 6; Akin, Burdick, and Amos, 1974). Table 3 shows variations in parenchyma bundle sheaths for blades of warm- and cool-season grasses. After 12 hours incubation with rumen microorganisms, the sheaths were mostly undegraded or only partially degraded in 3 of 4 warm-season forages. Conversely, in cool-season forages, more bundle sheath cells were partially or totally degraded. Additionally, comparisons using SEM of digested tissue in hybrids with higher digestibilities (i.e., CX-1 vs. CBG (Lowry et al., 1968); Kenhy vs. Ky-31 tall fescue (Buckner, Bush, and Burrus, 1972)) indicated that cell walls had been modified making them more digestible although anatomically the leaf blades were identical (Akin and Burdick, 1975). Accordingly, there appears to exist chemical-physical differences in the cell walls not discernible with this methodology that affects the ease of digestibility. These specific factors are not as yet defined; however, their elucidation would appear to be of significant value to forage breeders.

Table 4 shows differences in cell wall rigidity of parenchyma bundle sheaths stressed during preparation for SEM. Warm-season sheaths were 100% intact while many cool-season sheaths were partially collapsed. Extraction with acid detergent also revealed differential removal of similar tissues among forages and also indicated that inherent differences in cell walls may be related to digestibility (Akin, Barton, and Burdick, 1975).

Warm-season grasses are known to store starch grains preferentially in chloroplasts of parenchyma bundle sheath cells (Fig. 2) of leaf blades (Downton and Tregunna, 1968; Black and Mollenhauer, 1971). However, the fate of these highly nutritious starch grains in the digestion of structurally intact cells was not known. TEM of blades incubated with rumen microorganisms indicated that starch grains remained intact until cellulolytic bacteria degraded the cell wall, and then amylolytic bacteria hydrolyzed the starch grains (Fig. 10, 11). Starch *per se* is virtually 100% digestible (Dekker, Richards, Playne, 1972; Van Soest, 1967), and "starch, in common with soluble carbohydrates, exhibits a high percentage of conversion into fermentation products and cells" (Hungate, 1966). However, as shown earlier (Table 3) the ease of digestibility of parenchyma bundle sheaths and, therefore, apparently the ease of availability of nutrients contained therein, varies among forage types, species, and cultivars. This difference in availability of nutrients may be a factor associated with the relative nutritive value of forages. In regard to photosynthetic efficiency of warm-season (C4) grasses, Downton and Tregunna (1968) stated that "the breeding programs in which progeny are selected for lower rates of photorespiration, and the more efficient C4 pathway, offers attractive possibilities for increasing dry matter production". However, from Table 3 and Figures 10, 11, it would appear that breeding programs must be concerned, in addition to yields, with the digestibility of cell walls *per se* and, furthermore, perhaps even the availability of nutrients within certain slowly digested cells.

TABLE 4.--Percent structurally intact parenchyma bundle sheaths of warm-season and cool-season grasses after 72-hour incubation in control flasks

Grass	Percent Parenchyma Bundle Sheath		
	Intact*	Partially Intact+	Collapsed++
CBG	100	0	0
CX-1	100	0	0
PBG	100	0	0
Dallis	100	0	0
Brome	30.7	61.5	7.7
Orchard	0	50.0	50.0
Bluegrass	40.0	60.0	0
Timothy	50.0	50.0	0
Ky-31	71.4	28.5	0
Kenhy	57.8	42.1	0

* More than 3/4 of sheath cells structurally intact.
\+ At least 1 cell but no more than 3/4 of sheath cells structurally intact.
++ No sheath cells structurally intact.

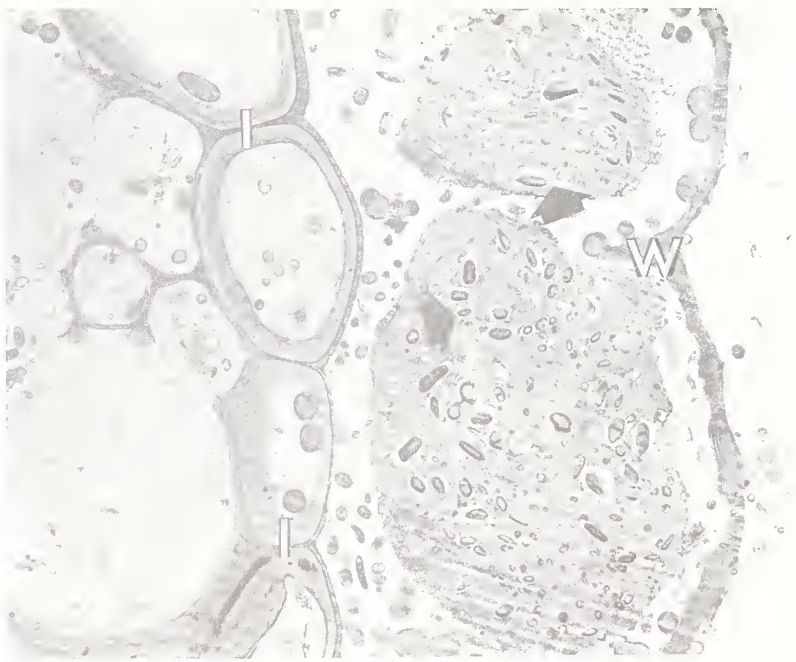

FIGURE 10.--TEM of Coastal bermudagrass blade degraded by rumen bacteria. Parenchyma bundle sheath cell walls (W) are partially degraded and many rumen bacteria adhere to the plant wall. Amylolytic bacteria have not yet hydrolyzed starch grains (arrows). The lignified, inner bundle sheath (I) is intact with few attached bacteria. X3,132.

From these data, the percentages of digestible tissue types and inherent cell wall differences (e.g., constituents, binding, or organization) appear to affect ease of digestion of leaf blades. Therefore, analysis for lignin or lignified tissue as a survey tool in breeding would provide information on the extent of blade digestibility, but not necessarily on the 'rate' of structurally intact blades. However, to fully understand plant digestion and the factors which affect it, one must examine all parts, i.e., blades, sheaths and stems, of grasses.

Stems and Sheaths. Previous work had indicated that factors (in particular lignin) in sheath and stems limit digestibility to a greater degree than those factors in leaves as plants mature (e.g., Pritchard, Folkins, and Pigden, 1963; Hanna, Monson, and Burton, 1976). To examine ultrastructural factors affecting digestibility with age of plant parts, we examined top, middle, and bottom portions of CBG blade, sheath, and stem grown for 5.5 months (greenhouse) to maximize factors limiting digestibility. We evaluated the portions for the histochemistry, chemistry, percent tissue type, IVDMD, and digestibility of the intact tissue (Akin, et al., 1977). Our data agreed with that of Hanna et al. (1976) on bermudagrasses evaluated at 1 and 4 weeks in that stem (and, in our work, sheath) portions decreased in digestibility with age, whereas blades did not. Our work indicated that the decrease in sheath and stem digestibility appeared to be caused by an increase with age in chlorine-sulfite positive lignification (not stainable with acid phloroglucinol) in the parenchyma cells. These cells, degraded in top portions, were not degraded in middle and bottom portions by rumen microbes after 72 hours (Fig. 12, 13). Furthermore, lignin percent increased over three percentage units and IVDMD decreased about 15 units with age (Akin et al., 1977). Recent investigations in our laboratory have indicated that, in 4 to 8 week old bermudagrass cultivars, parenchyma cells in bottom stems were often less rapidly digested; in certain cultivars (i.e., common and Coastal), portions of the parenchyma remained after 72 hours of microbial digestion. Hanna et al. (1976) reported that amounts of "anatomical components resistant to digestion" in stems did not permit differentiation of high- and low-quality bermudagrass genotypes at the same age; their light micrographs indicated resistance to digestion in some parenchyma cells of 4-week-old CX-1. Schank, Klock, Moore (1973) reported that the area of vascular tissue in stems did not increase from 5 weeks to maturity in limpograss. Furthermore, Pigden (1953) reported progressive lignification with age into the parenchyma cells of wheatgrass and bromegrass stems. From the available data, it would appear the breeders must evaluate factors in addition to vascular or thick-walled, fibrous tissue for limitations to stem digestibility. The extent of lignification may progress into stem parenchyma cells and impede degradation.

SUMMARY

TEM and SEM have been useful in evaluating the structurally intact cells of forage tissue for both ease (or relative rate) and extent of degradation by rumen microorganisms in vitro. Amounts of tissue types as well as inherent cell wall differences of tissue appeared to affect the digestion of leaf blades of forages reported herein. Certain cultivars, resulting in higher digestibility over other cultivars within species, were shown to have more rapidly digestible cell walls of similar tissues. Lignification of cell walls

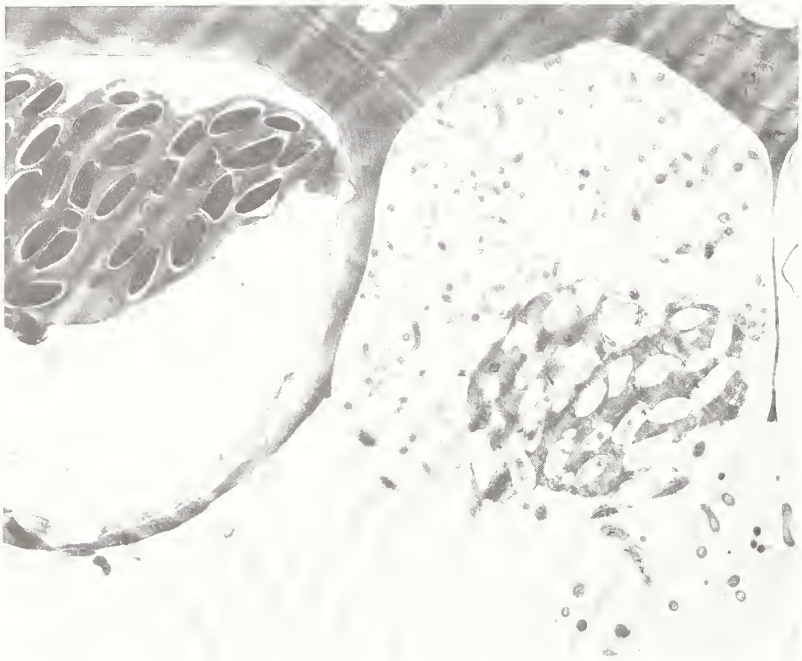

FIGURE 11.--TEM of Pensacola bahiagrass blade degraded by rumen bacteria. Cellulolytic bacteria apparently have degraded the wall of the parenchyma cell, and amylolytic bacteria have entered the cell and hydrolyzed starch grains; the adjacent cell's wall is undegraded, no bacteria have entered, and starch grains are intact. X4,698.

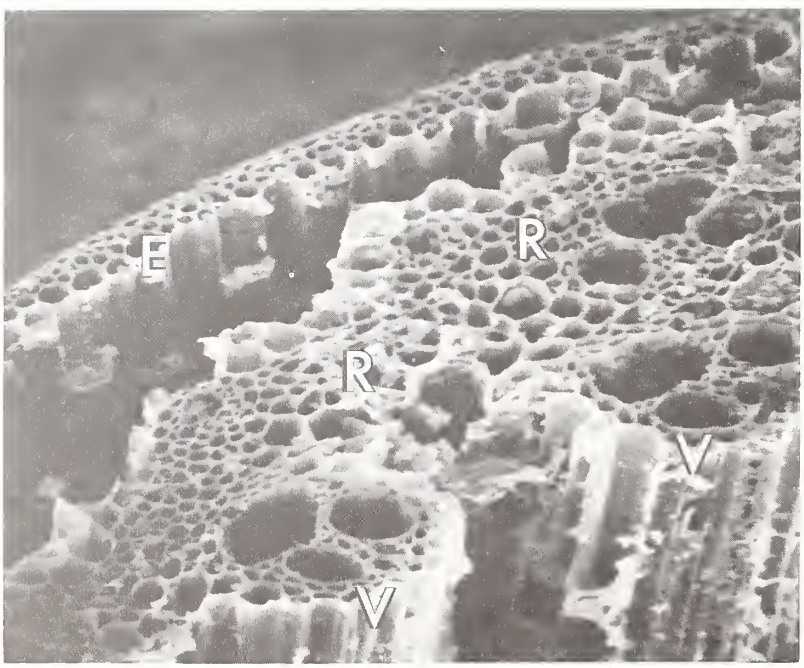

FIGURE 12.--SEM of top stem of Coastal bermudagrass incubated for 72 hours with rumen bacteria. Phloem, cortex, and parenchyma have been degraded leaving only the lignified epidermis (E), sclerenchyma ring (R), and vascular bundle (V). X374.

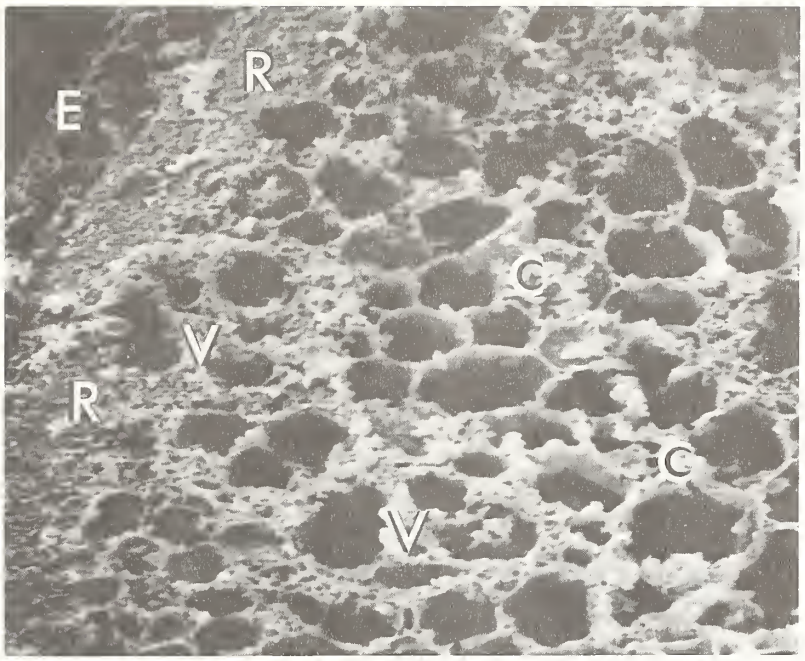

FIGURE 13.--SEM of bottom stem of Coastal bermudagrass incubated for 72 hours with rumen bacteria. Epidermis (E), sclerenchyma ring (R), vascular bundles (V) (except phloem), and parenchyma cells (C) are all undegraded. X374.

appeared to affect the extent of digestion in blades and certain tissues of stems. However, evaluation for the thick-walled sclerenchyma ring and xylem cells in stems may not in all forage species indicate limitations to the rate or extent of digestion with advanced maturity. These findings may be useful to plant breeders in developing forage varieties of improved nutritive value.

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TROPICAL GRASS BREEDING AND EARLY GENERATION TESTING WITH GRAZING ANIMALS

By K. H. Quesenberry, Rex L. Smith, S. C. Schank, and W. R. Ocumpaugh

Improvement of tropical and subtropical forage grasses by plant breeding may present some unique problems to the plant breeder. For instance, the range of adaptability of most tropical grasses has not been adequately determined. Plant breeders in the temperate areas may know that one or two grasses are adapted over a large area (tall fescue, bluegrass, orchard grass). However, the breeder of tropical grasses may be faced with making a choice among many species, each of which may only be suited to a relatively small land area. For example, past research in Florida has concentrated primarily on digitgrass (*Digitaria decumbens* Stent.) and bermudagrass (*Cynondon dactylon* (L.) Pers.) but, more recently, several other grasses such as limpograss (*Hemarthria altissima* (Poir.) Stapf et C. E. Hubb.), elephant grass (*Pennisetum purpureum* Schum.), buffelgrass (*Cenchrus ciliaris* L.), guineagrass (*Panicum maximum* Jacq.), Rhodesgrass (*Chlorida gayana* Kunth), pearl millet (*Pennisetum americanum* (L.) K. Schum.), and species of *Bracharia* and *Paspalum* have been evaluated. Some of these pasture grasses have shown promise, and breeding for improved yield and quality is being conducted. We believe that early generation evaluation of germplasm by grazing animals will facilitate more rapid and efficient selection of the germplasm best adapted to Florida pastures.

The first phases of evaluation will be carried out in the absence of grazing animals because emphasis in this stage is simply on reaction to environmental conditions. Reaction of the plant to defoliation must also be assessed. Where large numbers of different genotypes are involved, clipping is often the easiest method. Since it is well known that the effects of cutting and grazing may differ greatly, early generation testing under grazing can emphasize beneficial or detrimental traits of the grass.

SCHEME FOR FORAGE BREEDING AND EVALUATION

At Florida, the cooperating plant breeders, forage management specialists and animal scientists have developed a scheme for testing and evaluating forages. This scheme emphasizes early generation animal testing of new genotypes. Although the exact techniques and procedures may vary according to the type of forage being evaluated, the scheme can be divided into four main phases.

Phase I: Evaluation of Plant Introductions and Breeder Lines

The plant breeder is responsible for implementation of phase I. This phase may involve testing new species for tolerance to particular environmental conditions such as winter hardiness, disease and nematode susceptibility, and tolerance to temperature and moisture stress. It may also involve any of the more sophisticated breeding techniques for recombination of genetic material in species of proven adaptability. Plant material in this phase will generally be

evaluated as single plants or progeny rows with sufficient space allowed for development of stoloniferous or rhizomatous grasses. With certain breeding schemes, such as polycross progeny testing, evaluation of breeder lines in small plots may be necessary.

The agronomic measurements recorded in this phase will be determined by the particular objectives for a species and may include persistence, yield increase, pest resistance, regrowth, mode of reproduction, and seed set. Forage quality measurements in this phase may include chemical composition, *in vitro* organic matter digestibility, analysis for toxic substances, and leaf-stem ratios. This phase will mainly be conducted at the home base of the breeder with perhaps some testing at a second site.

Phase II: Regional Adaptation in Small Plot Clipping Trials

The plant material in phase II will include only superior genotypes from phase I. In a state such as Florida with wide climatic extremes, this phase requires the cooperation of agronomists at several branch stations. The plant breeder may also choose to distribute certain selected lines to cooperating scientists from other states in the region. Data collected from phase II experiments could be used as supplemental justification for release of selected genotypes as new cultivars. Testing of plant material in phase II should be conducted in enough locations to determine its area of adaptability.

Primary consideration will be given to plant response to climatic and soil conditions, varying levels of fertilization, and varying intervals of defoliation. Other parameters to measure at this phase will include seasonal yield, total yearly production, and response in grass legume mixtures. Forage quality-including IVOMD and chemical compostion, should be measured under the different environments and management schemes.

Phase III: Forage Response to Grazing Animals

Phase III involves plant defoliation and trampling by grazing animals. The plant material used in this phase may be identical to that in phase II or it may be select material from phase II. We feel that if phase II and phase III testing are conducted concurrently, the time from introduction to cultivar release will be shortened. This phase will require close cooperation between the plant breeder and the forage management specialist. It will also require development of several specialized small paddocks for restricting grazing animals to selected plants.

Selective grazing is one of the difficulties to be considered when evaluating forage plants under grazing. If only a few animals are placed in a paddock and allowed to stay for one or two weeks, the more palatable genotypes may receive a much more severe defoliation than the less palatable types. This problem may be overcome by "mob grazing". This technique involves confinement of a large number of animals to small paddocks and forcing the animals to graze all entries to a uniformly close height in two to four days. Although this type defoliation is different from that obtained under continuous grazing, it is similar to what could be experienced under rotational strip grazing and introduces the effects of trampling, pulling on the plants, and feces and urine. Since pastures under commercial conditions are likely to receive abuse, our goal with this mob grazing treatment is to determine which genotypes will withstand rather severe management.

Grazing management treatments may also be imposed in phase III on selected lines. The three main variables in any grazing management scheme are days of rest, days of grazing, and grazing pressure. The number of plots required to evaluate the practical range of these variables using routine experimental designs would be unmanageable. However, Mott and coworkers have shown that through use of the response surface designs, the number of pastures can be kept reasonably low while still evaluating the range of grazing management variables. This technique has proven particularly valuable in evaluating the effect of grazing management on the persistence of legumes at variable grazing pressures in newly developed grass cultivars. The response surface design has also been utilized to estimate which system of defoliation will result in maximum production of digestible energy. The effect of the various management regimes on IVOMD and other quality parameters should also be determined in phase III.

Phase IV: Animal Response to Forages

The objective of phase IV is to determine animal performance on potential new forage cultivars. The measurements will be taken to estimate animal gain per land area, carrying capacity per land area, voluntary intake, nutrient digestibility, forage quality prediction models, and forage yield in terms of feed units. Successful completion of this phase requires major assistance and cooperation from supportive animal scientists.

Two types of studies are possible in phase IV. The first would be an *in vivo* feeding trial. The objectives of this type of study would be to measure forage quality in terms of voluntary intake, *in vivo* digestibility, and rate of passage. Additional outputs from *in vivo* studies may be improved laboratory techniques for quality evaluation and development of models for forage quality prediction.

The second type study in phase IV will be grazing trials where the measurements are in terms of animal gain, carrying capacity, and effect of the forage on reproductive efficiency. Various systems of management, including continuous or rotational grazing and supplemental feeding, may be evaluated. Phase IV grazing experiments may also be designed to evaluate animal performance on new cultivars used as conserved forage such as silage, hay, or field stockpiled forage. Animal gains under various grazing pressures may also be evaluated. Phase IV studies utilizing animals as a tester are very expensive to conduct and should be designed to obtain the maximum information possible.

SUMMARY

A scheme for evaluation of tropical and subtropical forages in the shortest possible time should involve animal evaluation in early generation testing. We propose that phase III (plant response to grazing animals) testing be initiated concurrently with phase II (regional adaptation in small plots) testing. This early generation evaluation of plant response to animals, coupled with implementation of phase IV (animal response to plants) testing at the earliest date possible, will help to shorten the time to variety release.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the advice and cooperation of the entire forage breeding and management faculty of the Agronomy Department of the Unversity of Florida. The ideas presented in this paper are a synthesis of in-

puts from plant breeders, forage management specialists, and animal scientists. Special recognition is given to Dr. G. O. Mott for the original outline of the scheme which has been discussed in this paper.

SCHEME FOR FORAGE EVALUATION

Phase I

Plant Introductions and Breeder Lines

Preliminary testing of introductions and elite lines

Two locations
Spaced plants

Adaptability
Pest tolerance

Selection of Adapted Types

Phase II

Regional Small Plot Trials

Five locations
Small plots

Soil factors
Climatic factors
Fertility & clipping
Management

Phase III

Plant Response to Animal

Two locations
Small paddocks

Defoliation response
Response to grazing management

Selection of Elite Lines

Phase IV

Animal Response to Forage

Two locations
Large pastures

Animal gain
Carrying capacity
Voluntary intake and nutrient digestibility

BREEDING APOMICTIC GRASSES

By P. W. Voigt, B. L. Burson, and M. C. Engelke

At one time, apomixis (asexual reproduction from seed) was regarded as a block to breeding progress and an evolutionary deadend. However, research over the past 20 years has demonstrated that this is not true (Bashaw, 1975).

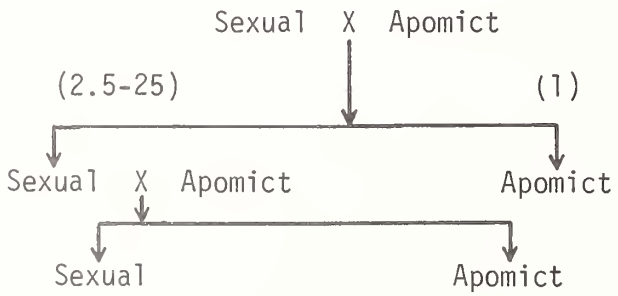
Facultative apomicts maintain their ability to produce new genotypes through occasional sexual reproduction. De Wet and Harlan (1970) have diagrammed the complex interrelationships within an agamic complex. Their research suggests how contact with sexuality can be maintained even across ploidy levels through diploid-tetraploid-haploid cycles. Thus, sexual forms through hybridization can generate new apomictic forms which can later revert to sexuality through haploidization.

Obligate apomictic biotypes are completely isolated from each other. However, contact can be reinitiated when sexual forms are found. In some species, diploid forms are a source of sexuality (Burton and Forbes, 1960). In others, recovery of sexuality may depend on the discovery of rare mutant plants (Taliaferro and Bashaw, 1966). New genotypes can then be generated and both sexual and apomictic types recovered.

Based on the genetic research reported in the literature, workable breeding schemes have been proposed for a number of apomictic grass species. The purpose of this paper is to present these schemes and to compare their efficiency in production of potentially useful apomicts. We will also present breeding schemes for Eragrostis curvula (Schrad.) Nees, based on our assessment of the present genetic knowledge of this species, and point out areas where additional evidence is needed.

Bahiagrass, Paspalum notatum Flugge

At the tetraploid level, bahiagrasses are normally obligate apomicts. However, induced tetraploids, from sexual diploids, reproduced sexually. Burton and Forbes (1960) used them as females in crosses with the apomictic tetraploids. They concluded that "obligate apomixis was controlled by a very few recessive genes." Based on their results, the following breeding scheme could be proposed.



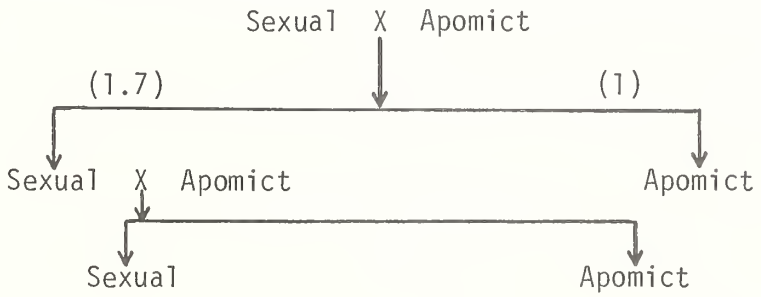
The exact ratio resulting from the initial cross could vary from 2.5 to 25 sexual for each apomict (Burton and Forbes, 1960). The genetic constitution of both parents influenced the frequency of apomictic hybrids. Thus, because the desired new cultivar would be an apomict, the choice of parents producing a high frequency of apomictic hybrids would be essential if high efficiency was to be obtained.

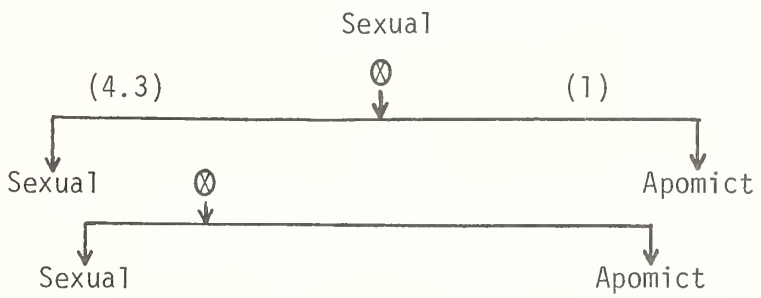
Sexual hybrids could be self pollinated to produce additional apomicts. However, F_2 plants from sexual hybrids were reduced in vigor (Burton and Forbes, 1960). The frequency of apomictic F_2's was also low, ranging from 1 apomict for each 30 to 230 sexual. Thus, self-pollination of sexual hybrids would not appear to be a viable breeding scheme for bahiagrass or for other species where inbreeding depression occurs.

A third potential breeding scheme would be to intermate sexual hybrids. Depending on the exact genotype, a certain number of apomictic plants might result, but most would probably be sexual. Thus, recurrent selection for yield or other characters could be attempted. Such an approach might provide access to the variability found among the naturally occurring apomictic tetraploids. Efficiency would depend on the ease of intermating. Sterility caused by cytological irregularities (Forbes and Burton, 1961) or other problems could limit the usefulness of this approach.

Buffelgrass, Cenchrus ciliaris L.

The inheritance of apomixis in buffelgrass and the closely related birdwoodgrass Cenchrus setigerus Vahl. has been clearly demonstrated (Taliaferro and Bashaw, 1966; Read and Bashaw, 1969). Results from hybridization between sexual and apomictic plants, and self-pollination of a sexual plant supported a two gene model, "where gene B conditions sexuality, and it is epistatic to gene A which conditions obligate apomixis." Two potential breeding schemes were described.





Clearly, the higher frequency of apomicts makes the hybridization scheme more efficient than the self-pollination scheme. However, sexual buffelgrass plants must be hand emasculated to produce the hybrids (Taliaferro and Bashaw, 1966). Apparently, sexual buffelgrass is normally self-pollinated and does not show inbreeding depression to the extent observed in bahiagrass (Burton and Forbes, 1960) or other normally cross-pollinated species. The cultivar 'Higgins' (Bashaw, 1968) was produced from self-pollination of sexual plant TAM-CRD B-1s. Thus, in buffelgrass both breeding schemes are viable approaches. Ratios obtained could vary with different sexual or apomictic genotypes.

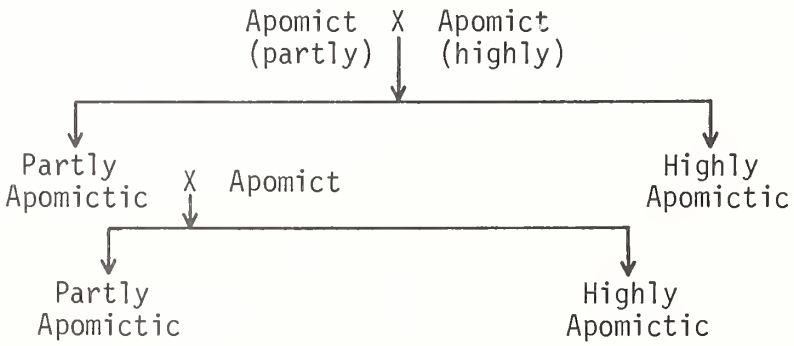
Apomictic breeding schemes can also be more effective than sexual schemes because apomixis can provide an escape from sterility. Read and Bashaw (1969) found that apomictic buffel-birdwoodgrass hybrids had 81% O.P. seed set compared to 42% for sexual hybrids. The value of apomixis, as an escape mechanism from sterility in interspecific and even some intergeneric crosses, has been demonstrated in several species, e.g., Harlan (1966); Dale et al. (1975).

Compared to bahiagrass, except in the need for hand emasculation, the breeding schemes now in use with buffelgrass appear more efficient than those possible with bahiagrass, because buffelgrass produces a higher percentage of apomictic offspring.

Kentucky Bluegrass, Poa pratensis L.

The inheritance of apomixis in Kentucky bluegrass, a facultative apomict, is not well understood. Different hypotheses have been proposed which range from apomixis as recessive to sexuality and due to a delicate genetic balance (Muntzing, 1940) to two complementary dominant genes required to make a plant moderately to highly apomictic (Funk and Han, 1967). The absence of a precise understanding of the inheritance of apomixis has not prevented its effective manipulation. In terms of released varieties (Funk et al., 1973; Funk et al., 1974; Peterson et al., 1975), the Kentucky bluegrass program at Rutgers University has been more effective than any other apomictic grass breeding program.

Although several breeding schemes have been proposed (Brittingham, 1943; Funk and Han, 1967), the most effective has been:



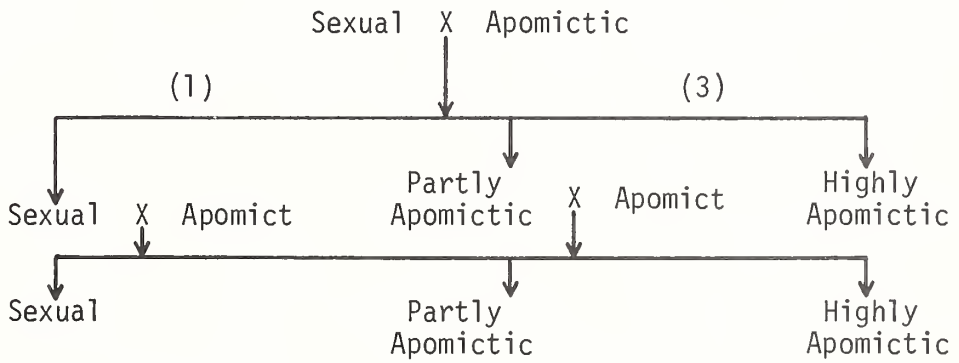
Highly sexual types have been developed and could be used as females but many of the most promising hybrids have been "triploids," plants from fertilization of an unreduced egg with reduced pollen (Pepin and Funk, 1971). All three released cultivars, 'Adelphi,' 'Bonnieblue,' and 'Majestic' were derived in that way. This increase in chromosome number has limited the effectiveness

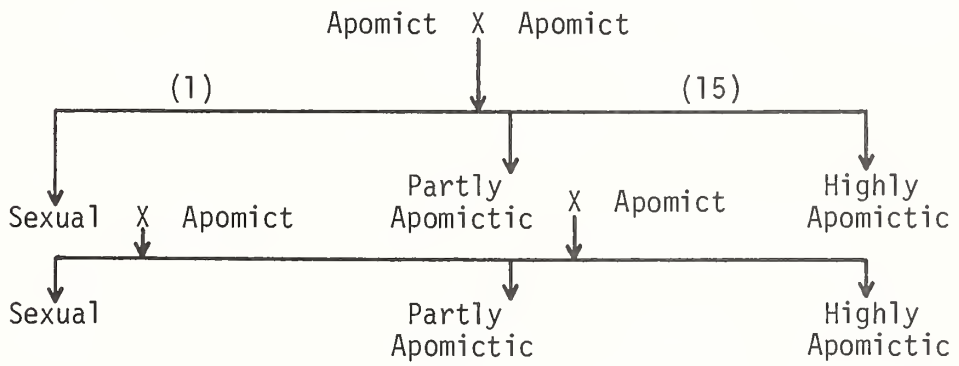
of the recurrent hybridization approach because plants with more than 100 chromosomes are usually reduced in vigor (Pepin and Funk, 1974).

The efficiency of apomictic breeding of Kentucky bluegrass can be quite high. Hybrids are not difficult to produce under controlled environmental conditions (Pepin and Funk, 1971). The choice of female parents determines the balance in efficiency between percentage of hybrids that are highly apomictic (potential cultivars) and percentage of plants that are maternal and not of hybrid origin. Also, the higher the level of apomixis in the parents, the greater the frequency of highly apomictic hybrids from the fertilization of reduced or unreduced eggs (Funk and Han, 1976).

Old World Bluestems, Bothriochloa, Dichanthium, and Capillipedium

In the agamic complex of old-world bluestems, the diploids are usually sexual, the tetraploids are facultative apomicts, and the higher polyploids are almost completely apomictic (Harlan et al., 1962). Sexual tetraploids were obtained by crossing a diploid X apomictic tetraploid (from fertilization of an unreduced egg) and an apomictic tetraploid X apomictic tetraploid (Harlan, 1966). From their genetic studies Harlan et al. (1964) concluded that apomixis was, "controlled by no more than one gene per genome." Apomixis was dominant to, but independent of, sexuality. From these results, two potentially useful schemes were proposed (Harlan, 1966).





Unlike bahiagrass, apomixis can be easily recovered in the hybrids. However, if the potentially more useful apomict X apomict cross is to be tried, hand emasculation and pollination would probably be necessary and large

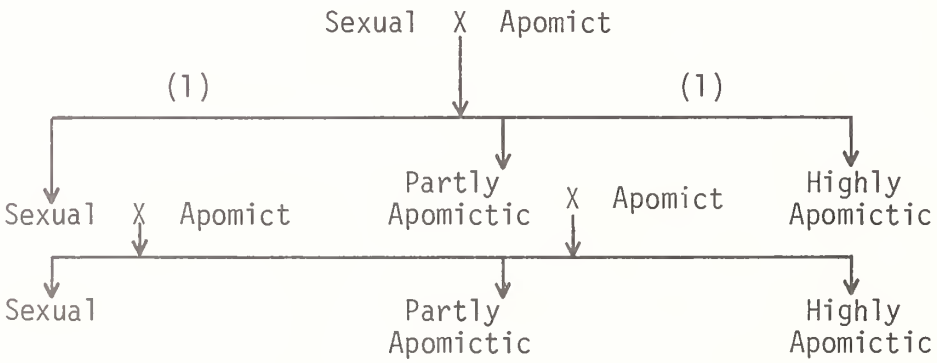
populations would have to be screened to separate maternal types from hybrids. Hybrids can also be produced from fertilization of unreduced eggs. This would increase the percentage of apomictic hybrids above 94% expected from the second scheme.

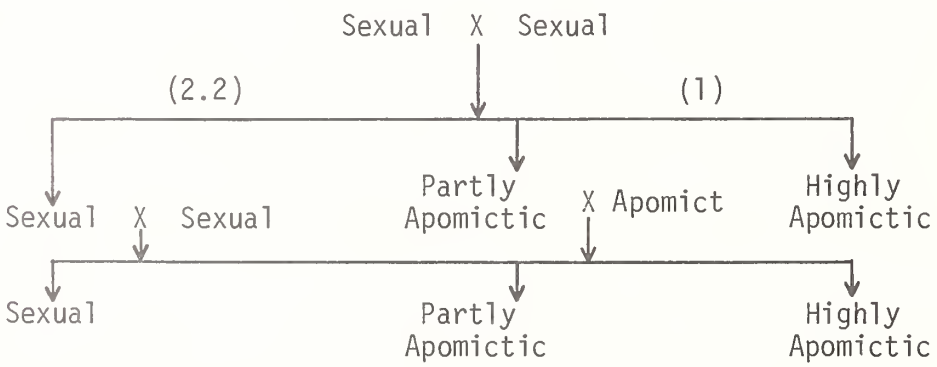
Possibly, the efficiency of hybrid production from facultative apomicts could be increased by manipulating the environment to increase sexual reproduction. Knox and Heslop-Harrison (1963) found up to 79% apomictic embryo sacs in Dicanthium aristatum (Poir.) grown under short days. Under long days the maximum percentage was only 47%. Thus, more hybrids from reduced eggs should be produced from pollinations of plants growing under a long day than a short day. A small effect of environment on percentage apomictic plants, 86% to 93%, was observed also in Poa pratensis (Hovin et al., 1977).

Guineagrass, Panicum maximum Jacq.

Guineagrass must be considered a facultative apomict because, despite the uniformity of many introductions, a low level of sexual reproduction occurs in natural populations (Warmke, 1954; Bogdan, 1963). Hybrids were produced by crossing sexual plants obtained from facultative apomicts or doubled diploids with apomictic plants (Smith, 1972; Hanna et al., 1973; Perenes and Rene-Chaume, 1973).

Most results published to date are in agreement with the two loci hypothesis concerning the genetics of apomixis proposed by Hanna et al. (1973). Two dominant alleles or more produce sexuality and one or no dominant alleles result in apomixis. Breeding schemes were proposed (Burton et al., 1973; Smith, 1974; Pernes et al, 1975).





The apomictic breeding system is highly efficient. Hybrids appear relatively easy to produce (Hanna et al., 1973) and a relatively high percentage of apomicts (50%) can occur in the F_1. Other genotypes could have different efficiencies in the production of apomicts. For example, an apomict, homozygous recessive at both loci, when crossed with sexual plants of the genotype reported by Hanna (AaBb) should produce three apomictic F_1's for each sexual F_1. Efficiency of apomictic breeding is reduced because some of the apomictic F_1's may have a higher level of sexuality than most naturally occurring apomictic strains (Perenes and Rene-Chaume, 1973).

Self- or cross-pollination of sexual plants would not be as efficient in the production of apomicts, because of the lower ratio of apomictic to sexual plants. Other possible sexual genotypes would produce even fewer apomictic offspring in the first generation.

Weeping Lovegrass, Eragrostis curvula (Schrad.) Nees.

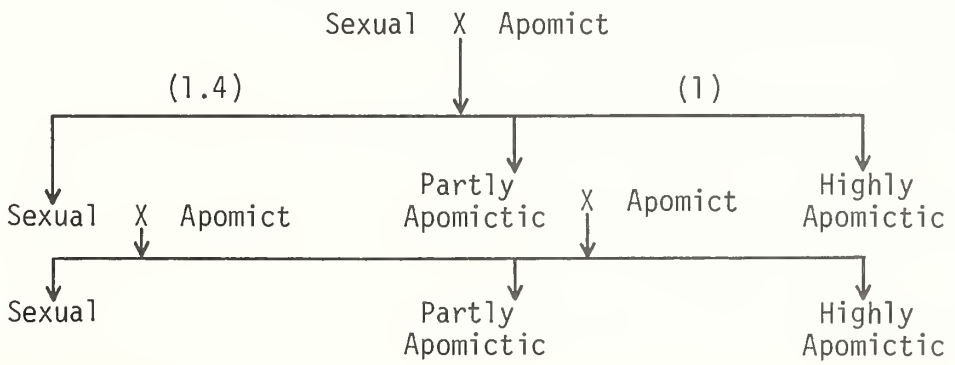
The inheritance of apomixis in E. curvula has not been determined. However, we have collected enough data to devise potential breeding schemes. Our results indicate that sexual plants, when self-pollinated, produce only sexual plants, as determined by cytological and progeny tests (Voigt and Bashaw, 1976). Of course, we cannot rule out the possibility that other sexual genotypes may exist that would segregate for mode of reproduction when self-pollinated.

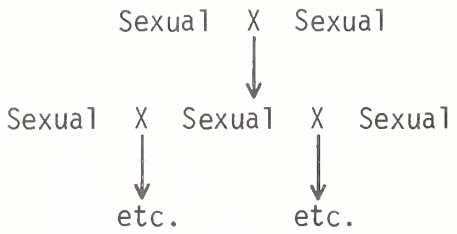
Numerous lovegrass hybrids have been produced. Our data indicate that the hybrids can be either sexual or apomictic (Voigt and Bashaw, 1976). Based on progeny tests, our present data suggest that the ratio is between 1.2:1 and 1.7:1 of sexual:apomictic F_1's, respectively. Other crosses may give different results.

The accuracy of progeny testing to determine mode of reproduction in a facultative apomict, such as E. curvula, is open to question. Our results suggest that in some cases, misclassifications can occur. We are using cytological data to determine the accuracy of our progeny tests. The value of progeny testing in determining mode of reproduction may vary with the amount of sexuality of the facultative apomictic parent(s).

The amount of sexuality varies among hybrids, e.g., 6% to 24% sexual (Voigt and Bashaw, 1976). Although we have not attempted to determine the amount of sexuality of natural ecotypes of E. curvula, the fact that until recently E. curvula was considered an obligate apomict (Voigt and Bashaw, 1973; Brix, 1974) suggests that the level is usually very low.

Potentially useful breeding schemes for E. curvula are:





The efficiency of the apomictic breeding scheme for E. curvula is similar to that for P. maximum. The advantages, relative ease of hybridization and a relatively high percentage of apomict hybrids, and the disadvantage of facultative apomixis, are the same. Because the inheritance of apomixis in E. curvula is not completely understood, we cannot predict what affect other genotypes than those already tested may have on the sexual to apomict ratio. Research is continuing in this area.

A second scheme involves interbreeding sexual plants. We cannot be sure, from present knowledge, that a totally sexual population can be developed at the tetraploid level. We are beginning research to find out.

This scheme is one easily adapted to recurrent selection. Although recurrent selection usually has not been considered for use with apomictic species, it could be useful to increase the frequency of desirable genes for quantitatively inherited chracteristics. The efficiency of this approach would depend on having genotypes that produce few or no apomictic offspring when intercrossed. If too many apomicts resulted, progeny tests would have to be used to detect apomictic plants, which could then be eliminated. This would reduce the effectivenesss of the procedure, because of the increased time and expense of these tests, unless a recurrent selection program for general or specific combining ability was desired.

Summary:

Apomictic breeding schemes can be more effective than sexual schemes. Apomixis can serve as an escape from sterility, thus, allowing use of a wider diversity of germplasm than is possible with sexual species. Each highly apomictic hybrid is a potential cultivar that can perpetuate hybrid vigor. Apomictic cultivars need only the minimal isolation distances required to prevent mechanical contamination. Their uniformity results in more uniform seed ripening than in many sexual species, thus, aiding in seed harvesting.

However, this same uniformity could provide a uniformly susceptible host for a disease or insect. This possibility should be countered by developing and releasing several cultivars, where wide spread use is anticipated, and by using several cytoplasms and numerous diverse genotypes in the breeding program.

Efficiency among apomictic breeding schemes depends on several factors.

1) The ease with which new, potentially useful apomictic genotypes can be created through crossing or selfing,
2) The frequency of occurrence of these genotypes in the created populations, and
3) The amount of sexuality in the apomictic hybrids.

When facultative apomicts are used as cultivars, the occurrence of aberrant plants is of concern. Where uniformity is of great importance, such as in turf, only the most apomictic plants can be considered for use as

cultivars. Breeder's increase fields should be space-planted so they can be effectively rogued. Seed increase probably should be limited to the foundation and certified classes.

Any consistent effect of environment on amount of facultative apomixis could be exploited. Higher levels of sexuality would be of great benefit in production of hybrids. Environmental manipulation to reduce the level of sexual reproduction in a facultative apomict would be of benefit to increase accuracy of progeny tests used for classifying mode of reproduction, and in achieving cultivar uniformity.

Some apomictic species produce a high percentage of sexual plants from certain sexual by sexual crosses. In these species the use of recurrent selection should be considered.

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THE OKLAHOMA BERMUDAGRASS BREEDING PROGRAM: OBJECTIVES AND APPROACHES

By C. M. Taliaferro, W. L. Richardson and R. M. Ahring

INTRODUCTIONS AND OBJECTIVES

With the development and release of 'Coastal' and 'Midland' bermudagrasses in 1943 and 1954, respectively, (2, 8) the image of bermudagrass was transformed from that of a dreaded "cotton patch" weed to that of a highly desirable pasture and conservation-use grass. The initial plant breeding work with bermudagrass in the U.S. was conducted, of course, by Dr. Glenn W. Burton, ARS Geneticist at the Coastal Plains Experiment Station, Tifton, Ga. It was his efforts largely, if not entirely, that gained due recognition for this important grass.

Genetic research with bermudagrass and other Cynodon species began in Oklahoma in the early 1960's. During that time Jack Harlan, J. M. J. deWet and W. W. Huffine made independent plant collection trips and amassed a worldwide collection of Cynodon germplasm (more than 700 accessions) at the Oklahoma State University. They conducted an extensive biosystematic study of the genus from 1963 to 1967 which elucidated phylogenetic relationships and eventually led to a revised taxonomic classification of the genus (9, 10, 11, 12, 13). In 1968, after Dr. Harlan's departure from OSU to a new post at the University of Illinois, the decision was made to begin a genetic improvement-varietal development program utilizing the vast and diverse storehouse of Cynodon germplasm that he and his colleagues had accumulated. The objectives of this breeding program are rather straightforward with the main emphasis on increasing the nutritive value while maintaining, and hopefully increasing, yield potential and adaptability. The good points and the bad points of widely grown bermudagrass cultivars like Coastal and Midland have been rather thoroughly discussed and characterized in the literature (4, 5, 7). Briefly, their high forage production potential per unit area together with their ability to persist under continuous and close grazing are, perhaps, their greatest assets. Their low or, at best, intermediate production potential per grazing animal is undoubtedly their greatest liability. It is toward an increase in this potential that our efforts are primarily directed. A somewhat secondary, but potentially important, endeavor in which we are involved is the development of winterhardy seed producing, seed propagated bermudagrass cultivars. These might be used for pasture purposes if their overall agronomic performance is competitive with vegetatively propagated cultivars but they should definitely be useful in establishing quick and permanent ground cover on areas where the primary concern is soil stabilization.

THE GERMPLASM BANK

Harlan's (10) revised classification of the genus Cynodon is presented in Table 1. He has discussed each of the 8 listed species and ten varieties in terms of their value for grazing and hay (14). The species and varieties that we are primarily using in our breeding program at present are: C. dactylon varieties dactylon and afghanicus, C. aethiopicus and C. nlemfuensis varieties nlemfuensis and robustus. Plants that are winterhardy and well adapted to Oklahoma come from the two varieties of C. dactylon. The latter two species represent robust East African types which, in general, seem to have the highest nutritive value but are not winterhardy. Major differences between the temperate and tropical types are listed in Table 2. The major task before us, obviously, is to genetically incorporate the desirable attributes of the two types into an agronomically acceptable cultivar. All of the species and varieties listed are highly cross-pollinated, genetically heterozygous and heterogeneous and rather easily crossed at the varietal and species levels. Cynodon dactylon var. dactylon is enormously variable but from the temperate germplasm available in this taxon we have yet to find a plant with outstanding nutritive value. However, I would wholeheartedly agree with Burton (6) who recently expressed his belief that the potential is excellent for developing high quality, winterhardy bermudagrass cultivars. As he pointed out both characters are heritable, parents excelling in one or the other of these characters are available and there is no evidence indicating that they are incompatible.

THE APPROACH

Vetetatively Propagated Bermudas

Crosses between temperate, low quality and tropical, high quality Cynodons produce variable progenies whose average values for hardiness and quality usually approach the midparent value. In large hybrid populations, however, individual plants can usually be found which equal, and sometimes exceed the hardiness or quality of the parent excelling in the respective trait. Unfortunately we have not as yet found a single hybrid plant excelling in both characteristics. Winterhardiness is undoubtedly conditioned both by rhizome production and by tissue hardiness. The species C. aethiopicus and C. nlemfuensis are nonrhizomatous. Although we have attempted no genetic study of the inheritance of rhizome production we have backcrossed hybrid plants to hardy parents and selected from these backcross progeny rhizomatous plants with reasonably good hardiness. These selected plants retained some of the characteristics of the tropical parents eg. certain morphological characteristics, fast initial spread potential and most significantly, a reasonably increased level of quality. As an example, in 1973 we selected from 900 such progeny five genotypes which we have subsequently yield tested for two years in a preliminary trial on one of our research stations near Chickasha, Oklahoma. The forage yields of the five selected genotypes plus that of the variety 'Hardie' are given in Table 3. The best hybrid, 71 X 6-7, has yielded 26% more forage than Hardie, this being a statistically significant difference.

Table 1. A revised classification of the genus Cynodon*

Epithet	Chromosome Number	Distribution
C. aethiopicus Clayton et Harlan	18, 36	East Africa: Ethiopia to Transvaal
C. arcuatus J. S. Presl ex C. B. Presl	36	Malagasy, India, S. E. Asia, S. Pacific to Australia
C. barberi Rang. et Tad.	18	India
C. dactylon (L.) Pers.		
var. dactylon	36	Cosmopolitan
var. afghanicus Harlan et deWet	18, 36	Afghanistan
var. aridus Harlan et deWet	18	South Africa northward to Palestine, east to South India
var. coursii (A. Camus) Harlan et deWet	36	Madagascar
var. elegans Rendle	36	Southern Africa, south of lat. 13° S.
var. polevansii (Stent) Harlan et deWet	36	Near Baberspan, S. Africa
C. incompletus Nees		
var. incompletus	18	Transvaal to Cape
var. hirsutus (Stent) deWet et Harlan	18, 36	Transvaal to Cape
C. nlemfuensis Vanderyst		
var. nlemfuensis	18, 36	Tropical Africa
var. robustus Clayton et Harlan	18, 36	East Tropical Africa
C. plectostachyus (K. Schum.) Pilger	18	East Tropical Africa
C. transvaalensis Burtt-Davy	18	South Africa

*After Harlan, J. R. (10)

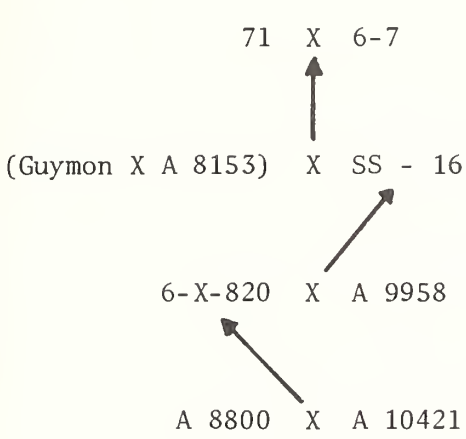
Table 2. Major Differences Between Temperate and Tropical Cynodons.

Character	Temperate	Tropical
Initial spread	Slow	Fast
Rhizomes	Abundant	Few to none
Tenacity	Strong	Weak
Nutritive value	Lowest	Highest

Table 3. Yields of Five Bermudagrass Selections and the Variety Hardie. Chickasha, Oklahoma 1975-76.

Selection or Variety	Tons Dry Matter/Acre			% of Hardie
	1975 3-cuts	1976 2-cuts	75-76 Avg.	
71 X 6-7	5.56	5.09	5.32	126
71 X 8-3	5.31	4.22	4.77	113
71 X 8-4	5.23	4.23	4.73	112
71 X 11-5	5.08	4.14	4.61	109
71 X 306	4.48	4.21	4.34	103
Hardie	4.88	3.57	4.23	100

The pedigree of 71 X 6-7 traces to an original cross between a well adapted, rhizomatous, temperate parent and a nonrhizomatous, tropical parent as follows:



Guymon = C. dactylon var. dactylon
A 8153 = C. dactylon var. afghanicus
A 9958 = C. dactylon var. dactylon
A 8800 = C. dactylon var. afghanicus
A 10421 = C. dactylon var. robustus

In addition to its apparent good yield potential 71 X 6-7 has exhibited in this one preliminary trial a rapid establishment capacity, the formation and maintenance of a reasonably thick and uniform sod and a spring recovery and spring growth capability not too different from that of conventional cultivars such as Midland and Hardie. Tentative measurements of its quality are however, conflicting, some indicating excellent quality while others indicate only a modest level of digestibility. The SS-16 plant list above is also an interesting hybrid. It has better than average quality and the robust growth potential of its tropical parents, along with abundant rhizome production and good winterhardiness. Its robust growth potential usually is exhibited only during the year of establishment. In subsequent years, its forage yield has been disappointingly low except under conditions of high N fertilization and irrigation in dry periods. However, we believe that 71 X 6-7 and other progeny that we have selected from crosses involving SS-16 as a parent demonstrate that it does not transmit this low yield characteristics to all of its progeny. I believe that these results further demonstrate that progress is being made in the incorporation of desirable attributes from the temperate and tropical Cynodons into individual genotypes. The key to eventual success appears to be continued energetic efforts in breeding and utilization of the best selection and evaluation tools that we have available. The IVDMD and NBDMD procedures for estimating forage quality have been of immense value in selecting for higher forage quality, but still faster methods are needed that will allow breeders to evaluate even larger numbers of progeny plants.

Seed Producing-Seed Propagated Bermuda Research

We have identified and isolated Cynodon accessions and hybrids from our germplasm collection that have good seed set and good seed production potential. In an initial study conducted in 1971-72 the best of these fertile selections produced 2-year average open-pollinated seed yields of 969 Kg/ha (1).

These and other fertile clones that we have subsequently identified and selected are cross fertile but highly self-incompatable with the majority of the clones setting less than 1.0% seed when selfed. We have found a few clones that consistently set a much higher than average percentage of seed under self-pollination indicating that the intensity of the self-incompatibility mechanism does vary in bermudagrass.

We have used select fertile bermuda clones to produce experimental synthetic varieties which are now in the initial stages of evaluation. Two clone synthetics, generated by planting alternating strips of two fertile clones in seed production fields have been produced for four different clonal combinations. Seed production from these fields has been quite acceptable for the past two years ranging from 400 to 700 lbs/A. As Burton (3) suggested this would be an ideal way to commercially produce F_1 hybrid seed, the essential prerequisites being sufficiently fertile parents to make it economically feasible and, of course, an F_1 hybrid population with acceptable performance characteristics. Open-pollinated progeny from our clones and synthetic varieties are, as expected, highly variable both in terms of morphology and fertility. We have initiated breeding work designed to increase the level of fertility and other desirable characteristics in this germplasm.

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THE PROPOSED ESTABLISHMENT OF HAY STANDARDS

By R. F Barnes, D. A. Rohweder, and N. Jorgensen

Hay is big business in the United States. Over $6.5 billion worth of hay was produced in 1975 (1). Over 20 percent of the hay is marketed as a cash crop that is eventually fed to livestock. Wide variations in the percentage of hay sold exist among States. In Arizona and California approximately 75 percent of all hay is sold off the farm where produced; in Wisconsin, the largest hay producer in the United States, less than 10 percent is normally sold off the farm. Increasing feed costs in the face of continuing demands for ruminant livestock products have focused attention on the real and potential value of the Nation's hay crop.

HAY MARKETING TASK FORCE

In 1972 the American Forage and Grassland Council (AFGC) formed a Hay Marketing Task Force to (a) identify hay marketing problems, (b) determine problem priorities and possible practical solutions, and (c) develop specific recommendations for action. A Forage Analysis Subcommittee was given the charge of establishing a system for pricing hay based upon some realistic measurement of feed value. Numerous reports have been prepared and talks given based upon the Subcommittee's findings (2, 5, 9, 10).

In April 1975 the Subcommittee cosponsored a Hay Quality and Analysis Roundtable (7) at Beltsville, Maryland, which set the stage for the development of two important programs. The use of infrared reflectance for estimating chemical composition of forage samples was first reported at that meeting. The information presented has been subsequently published (6). The potential for such instrumentation continues to be promising, and an update on its current status was reported earlier in this conference.

At the same meeting, the merits of revising the Federal hay grades were considered, and a decision was made to pursue the establishment of new hay standards based upon chemical composition as related to animal response data. The present Federal hay grades were authorized by the Agricultural Marketing Act of 1946 and were last revised in the Handbook of Official Hay and Straw Standards in 1949 (4). These grades are based on organoleptic properties (subjective properties based upon color, texture, odor, and flavor), leafiness and botanical composition and on the presence or absence of foreign material. These are all qualitative properties subject to variable scoring and to erroneous estimates of feeding value. At present the functions associated with the inspection and standardization of grain and hay have been transferred from the Agricultural Marketing Service to the Federal Grain Inspection Service (FGIS). The FGIS was established by PL94-582 as of November 1976. Today there are only a half dozen qualified hay inspectors

in the United States, and less than 300 lots of hay were inspected this past year.

FORAGE ANALYSIS SUBCOMMITTEE

In 1974 the Forage Analysis Subcommittee surveyed U.S. scientists and extension personnel working with forage quality and animal nutrition to obtain a consensus of opinion relative to more precise techniques for evaluation of forage quality. The majority of the respondents indicated that analyses for acid detergent fiber (ADF) and neutral detergent fiber (NDF) (3) were the chemical assays of choice for estimating *in vivo* digestible dry matter (DDM) and dry matter intake (DMI), respectively. The subcommittee obtained forage samples with known analytical data from a number of locations to determine the precision of the above relationships. Data, including ADF, NDF, and the *in vivo* measurements of DDM and DMI, were obtained from Florida, Indiana, Wisconsin, and Pennsylvania (9, 11). The plant species included in the initial study were alfalfa (*Medicago sativa* L.), smooth brome (*Bromus inermis* Leyss.), orchardgrass (*Dactylis glomerata* L.), reed canarygrass (*Phalaris arundinacea* L.), tall fescue (*Festuca arundinacea* Schreb.), 'Pangola' digitgrass (*Digitaria decumbens* Steut.), bahiagrass (*Paspalum notatum* Flügge), and 'Suwannee' bermudagrass (*Cynodon dactylon* (L.) Pers.).

The relationships of chemical composition to *in vivo* measurements were estimated by regression analysis. A combination of ADF and NDF were used to provide an estimate of digestible dry matter intake (DDMI) for a forage as follows:

DDM (%) is inversely related to ADF concentration; i.e., DDM decreases as ADF increases.

DMI expressed in terms of animal body weight in kilograms to the 0.75 power is inversely related to NDF concentration; i.e., DMI decreases as NDF increases.

DDMI, expressed in the same terms as DMI, is equal to DDM X DMI/100.

PROPOSED HAY STANDARDS

The new hay standards proposed by the Forage Analysis Subcommittee (9, 11) are presented in Tables 1 and 2. Legumes, grasses, and legume-grass mixtures are evaluated in a continuum, allowing a calculation of feeding value for all types of plants. Both organoleptic characteristics and representative chemical analyses (crude protein, ADF, and NDF) are used to establish five grades with one sample grade. The grades are based on advancing stages of maturity and are designed to represent measurable differences in animal response. The knowledge that the intake potential of hay can be just as important as digestibility led to consideration of these two characteristics in combination to give an estimate of DDMI. The DDMI was then used to predict the relative feed value by which an equitable pricing system can be established. Relative feed value is calculated from DDMI by multiplying the latter by 2.5 (a DDMI value of 40 is arbitrarily designated as a relative feed value of 100). The formulas used to calculate relative feed value are

TABLE 1.--Proposed market hay grades for legumes and legume-mixtures (Hay Marketing Task Force).

Grade	Stage of Maturity International Term	Definition	Physical Description	Typical Chemical Composition - %[1] CP %	ADF %	NDF %	Relative Feed Value %
1. Legume hay	Pre bloom	Bud to first flower; stage at which stems are beginning to elongate to just before blooming.	40 to 50% leaves[2]; green; less than 5% foreign material; free of mold, musty odor, dust, etc.	>19	<31	<40	>140
2. Legume hay	Early bloom	Early to mid bloom; stage between initiation of bloom and stage in which 1/2 of the plants are in bloom.	35 to 45% leaves[2]; light green to green; less than 10% foreign material; free of mold, musty odor, dust, etc.	17-19	31-35	40-46	124-140
3. Legume hay	Mid bloom	Mid to full bloom; stage in which 1/2 or more of plants are in bloom.	25 to 40% leaves[2]; yellow green to green; less than 15% foreign material; free of mold, musty odor, dust, etc.	13-16	36-41	47-51	101-123
4. Legume hay	Full bloom	Full bloom and beyond.	Less than 30% leaves[2]; brown to green; less than 20% foreign material; free of musty odor, etc.	<13	>41	>51	≤100
6. Sample Grade[3] Hay which contains more than a trace of injurious foreign material (toxic or noxious weeds and hardware) or that definitely has objectionable odor or is under cured, heat damaged, hot, wet, musty, moldy, caked, badly broken, badly weathered or stained, extremely overripe, dusty, which is distinctly low quality or contains more than 20% foreign material or more than 20% moisture.							

[1] Chemical analyses expressed on dry matter basis. Chemical concentrations based on research data from NC and NE States and Florida. Dry Matter (moisture) Concentration can affect market quality. Suggested moisture levels are: Grades 1 and 2 < 14%, Grade 3 < 18%, and Grade 4 < 20%.

[2] Proportion by weight.

[3] Slight evidence of any factor will lower a lot of hay by one grade.

CP = Crude Protein; ADF = Acid Detergent Fiber; NDF = Neutral Detergent Fiber; Relative Feed Value is based on Digestible Dry Matter Intake. See Table 3.

TABLE 2.--Proposed market hay grades for grasses and grass-legume mixtures (Hay Marketing Task Force).

Grade	Stage of Maturity International Term	Definition	Physical Description	Typical Chemical Composition - %[1] CP[2] %	ADF %	NDF[3] %	Relative Feed Value %
2. Grass hay	Pre head	Late vegetative to early boot; stage at which stems are beginning to elongate to just before heading; 2 to 3 weeks' growth.[5]	50% or more leaves[4]; green; less than 5% foreign material; free of mold, musty odor, dust, etc.	>18	<33	<55	124-140
3. Grass hay	Early head	Boot to early head; stage between late boot where inflorescence is just emerging until the stage in which 1/2 inflorescences are in anthesis; 4 to 6 weeks' growth.[5]	40% or more leaves[4]; light green to green; less than 10% foreign material; free of mold, musty odor, dust, etc.	13-18	33-38	55-60	101-123
4. Grass hay	Head	Head to milk; stage in which 1/2 or more of inflorescences are in anthesis and the stage in which seeds are well formed but soft and immature; 7 to 9 weeks' regrowth.[5]	30% or more leaves[4]; yellow green to green; less than 15% foreign material; free of mold, musty odor, dust, etc.	8-12	39-41	61-65	83-100
5. Grass hay	Post head	Dough to seed; stage in which seeds are of dough-like consistency until stage when plants are normally harvested for seed; more than 10 weeks' growth[5]	20% or more leaves[4]; brown to green; less than 20% foreign material; slightly musty odor, dust, etc.	<8	>41	>65	<83
6. Sample Grade[6] Hay which contains more than a trace of injurious foreign material (toxic or noxious weeds and hardware) or that definitely has objectionable odor or is under cured, heat damaged, hot, wet, musty, moldy, caked, badly broken, badly weathered or stained, overripe, dusty, which is distinctly low quality, or contains more than 20% foreign material or more than 20% moisture.							

[1] Chemical analyses expressed on dry matter basis. Chemical concentrations based on research data from NC and NE States and Florida. Dry Matter (moisture) Concentration can affect market quality. Suggested moisture levels are: Grade 2 < 14%, Grade 3 < 18%, and Grades 4 and 5 < 20%.

[2] Fertilization with nitrogen may increase CP concentration in each grade by up to 40 percent.

[3] Tropical grasses may have higher NDF concentrations than indicated in this table.

[4] Proportion by weight.

[5] For grasses that do not flower or for which flowering is indeterminant.

[6] Slight evidence of any factor will lower a lot of hay by one grade, except Grade 5.

CP = Crude Protein; ADF = Acid Detergent Fiber; NDF = Neutral Detergent Fiber; Relative Feed Value is based on Digestible Dry Matter Intake. See Table 3.

presented in footnote to Table 3. They were derived from regression analyses of DDM and DMI data for forages of known composition fed to sheep.

The organoleptic descriptions used in the old standards are used only as descriptive characteristics rather than as absolute grade determinants. Consideration is also given to moisture level and to injurious foreign material (toxic or noxious weeds and hardware) as secondary characteristics that may affect hay quality and value.

Typical concentrations of crude protein (CP), ADF, and NDF for the various stages of maturity in legumes and predominantly legume mixtures are given in Table 1, and those for grasses and predominantly grass mixtures in Table 2. If expected CP values are not reached or if moisture and/or quantities of foreign material exceed set limits, a basis exists for lowering the grade established by prediction of digestible dry matter intake alone. CP concentration is important to nutriment and is often positively correlated with energy availability, but CP is not considered a primary factor in calculating relative feed value because climate and fertilizer may modify this relationship in forages. The best pure grass hays will usually grade no higher than a grade 2 legume hay. This is because grasses usually contain far more NDF and have lower intake potential than legumes. At low levels of nitrogen fertilizer, grasses also contain less CP than legumes.

HAY PRICING

Relative feed values range from over 140 percent for early-cut legumes to less than 83 percent for late-cut grasses. If one assumes a base price of $50 per ton for a mature legume hay having a relative feed value of 100 (Grade 4), hay prices will range from less than $42 per ton to over $70 per ton, depending on quality. The base price can readily shift with the current market situation in localized areas. This system would provide a far more equitable determination of hay price than that currently existing.

A comparison has been made between the proposed market hay grades and actual sales of 268 lots of hay in Wisconsin in 1976 (Table 4) (8). These lots could be identified according to stage of maturity and other characteristics into the five proposed hay grades. A significant aspect of the information is that the range in market price within any one grade was considerably greater than would be anticipated for that specific grade. For instance, the range in value for grade 4 was $32 to $100 with the upper limit exceeding the average price for grade 1. The value based on corn at $2.50 per bushel or soybeans at $10 per hundredweight and relative feed values are also given.

PRESENT STATUS

It must be recognized that the proposed hay standards are in the process of evolving. Further, it is urged that flexibility be allowed in updating the proposed standards as more data become available. The availability of samples for which there is adequate animal data and reliable information about agronomic characteristics is limited. Also, subtropical species may not fit the

TABLE 3.--Typical composition of Digestible Dry Matter (DDM), Dry Matter Intake (DMI), and Digestible Dry Matter Intake (DDMI) for proposed market hay grades described in Tables 1 and 2[1/]

Grade	Legume hays			Grass hays			Relative Feed Value - %[2/]
	In vivo DDM %	DMI gm/W kg $^{0.75}$	DDMI gm/W kg $^{0.75}$	In vivo DDM %	DMI gm/W kg $^{0.75}$	DDMI gm/W kg $^{0.75}$	
1.	>70	>80	>57	---	---	---	>140
2.	66-70	75-80	50-57	>72	>69	>49	124-140
3.	58-65	68-74	41-49	62-72	65-69	41-49	101-123
4.	<58	<68	<41	55-61	59-64	33-40	83-100
5.	---	---	---	<55	<59	<33	<83

[1/] Formulas used to calculate relative feed value: Legume--DDM = 65.5 + 0.975 ADF% - 0.0277 ADF%^{2}; DMI = 39 + 2.68 NDF% - 0.0410 NDF%^{2}; Grasses--DDM = 34.8 + 2.56 ADF% - 0.0491 ADF%^{2}; DMI = 54.8 + 1.22 NDF% - 0.0176 NDF%^{2}; DDMI = DDM X DMI/100; Relative Feed Value = DDMI X 2.5; where DDM = In vivo dry matter digestibility; DMI = dry matter intake; DDMI = digestible dry matter intake.

[2/] Relative feed value is an estimate of overall forage quality. It is calculated from intake and digestibility of dry matter when forages of known composition were fed to sheep. The values are relative; however, they are equally appropriate for all classes of livestock. Relative feed value estimates the intake of digestible energy when the forage is the only source of dietary energy and protein.

TABLE 4.--Comparative identification of hay grades with selected hay sales in 1976[1/]

Grade	No. of Lots (%)	Average Price ($)	Range in Value ($)	Value Based on Corn $2.50/bu Soybeans $10/cwt.	Value Based on Relative Feed Value ($)
1	26 (10)	84	62 - 110	$84	> 84
2	68 (25)	75	50 - 125	75	74 - 84
3	80 (30)	65	37 - 90	65	60 - 74
4	67 (25)	58	32 - 100	60	50 - 60
5	27 (10)	44	30 - 75	45	< 50
Total	268				

[1/] Compiled Dec. 8, 1976, by Dr. D. A. Rohweder.

proposed standards; however, it may be possible to use hemicellulose values to overcome any discrepancies that may occur.

Alternative approaches to the implementation of a hay grading system may include (a) the establishment of new Federal hay grades to be monitored by the FGIS through a cadre of trained hay inspectors, (b) the establishment of new Federal hay grades by the FGIS to be used by an established trade association, by commercial laboratories, or by the Cooperative Extension Service, or (c) the establishment of hay grades under the auspices of a trade association that could then be monitored by the association. The proposed hay standards have been submitted to the FGIS for their review. At this time, it is not known which of the approaches, or what additional approach, might be pursued. However, it is unlikely that the proposed standards will be adopted in final form sooner than 2 years from now. Meanwhile, it is urged that the proposed assays be used so as to further test their validity in obtaining realistic estimates of the feeding value of hay for marketing and feeding programs. It is essential that a rapid, accurate, and relatively inexpensive analytical procedure be available for use in any effective hay marketing situation. It is hoped that the infrared reflectance technique will meet this need.

SUMMARY

The Hay Marketing Task Force of the American Forage and Grassland Council has proposed a new system for establishing feeding value and equitable market pricing of hay. The system consists of five market grades plus a sample grade that would replace an outdated and cumbersome system of establishing Federal hay grades devised in the 1940's.

The new system is based upon the concept of defining feeding value according to chemical composition as related to animal response. The two primary determinants are concentrations of acid detergent fiber (to estimate digestibility) and neutral detergent fiber (to estimate intake potential). Other characteristics that would determine a given grade include stage of maturity, crude protein concentration, moisture level, and degree of contamination with injurious foreign material.

An expression of relative feed value is calculated from an estimate of digestible dry matter intake to permit an evaluation of all hays on a continuum. An equitable price for the hay can then be calculated from a localized base price for a Grade 4 hay that has a relative feed value of 100.

To make the new system workable, faster assays of fiber components and crude protein are needed for small lots of hay that are in transit.

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SOUTHERN FORAGES IN THE NEW HAY STANDARDS

By John E. Moore

The proposal of new hay quality standards by the American Forage and Grassland Council (AFGC) is an important step forward in the practical application of forage quality principles. The new standards are based upon voluntary Digestible Dry Matter Intake (DDMI). This parameter is closely related to Digestible Energy intake and animal performance, and is an acceptable measure of overall forage quality.

The objective of this paper is to discuss tropical grasses used for hay in the South in terms of the AFGC standards. Intake, digestibility and hay grades based upon actual *in vivo* trials will be compared to similar values predicted by AFGC equations based on chemical composition.

FORAGES AND ANALYSES

This study involved 82 hays of eight tropical grasses: Pensacola and Paraguay 22 bahiagrass (*Paspalum notatum*); Alicia, Coastal, Coastcross I, Common and Suwannee bermudagrass (*Cynodon dactylon*); and Pangola digitgrass (*Digitaria decumbens*). The hays were harvested in Florida and Louisiana after regrowths ranging from 2 to 12 weeks and fed to mature wether sheep in individual digestion cages. Dry matter digestibility (DMD) and dry matter intake (DMI) were measured.

Samples of each hay were analyzed for acid-detergent fiber (ADF) and neutral-detergent fiber (NDF). These values were used to compute a predicted DMD and DMI for each hay using the following AFGC equations:

$$DMD,\% = 34.8 + 2.56(ADF) - .0491(ADF)^2$$

$$DMI,g/BW^{.75} = 54.8 + 1.22(NDF) - .0176(NDF)^2$$

DIGESTIBILITY AND INTAKE

Figures 1 through 6 illustrate the relationship between chemical composition and actual *in vivo* data for each of the 82 hays. Superimposed on each figure is a solid line representing predicted values according to AFGC equations.

There was a close relationship between predicted and actual DMD of Florida Pangola digitgrass and Pensacola bahiagrass (Fig. 1). However, AFGC equations overestimated the DMD of Suwannee bermudagrass (Fig. 1) and Louisiana forages (Fig. 2 and 3). The data suggested that ADF may not be a generally acceptable predictor of DMD.

Florida data suggested that there was a relationship between NDF and DMI for Pangola digitgrass, but the AFGC equation did not describe this relationship (Fig. 4). For Florida Suwannee bermudagrass (Fig. 4) and the Louisiana

forages (Fig. 5 and 6), the AFGC equation underestimated DMI. The data suggested that NDF may not be a generally acceptable predictor of DMI.

HAY GRADES

In the AFGC system, hay grades are based upon DDMI($g/BW^{.75}$) which is the product of DMD times DMI. The following standards have been proposed:

Grade	DDMI, $g/BW^{.75}$
1	>56.0
2	49.6 - 56.0
3	40.1 - 49.5
4	34.0 - 40.0
5	<34.0

In this study, DDMI was calculated in two ways: (1) using actual DMD and DMI values, and (2) using predicted DMD and DMI values. Figures 7 and 8 illustrate the relationships between predicted and actual DDMI values for the Florida and Louisiana hays, respectively. Superimposed upon Figures 7 and 8 are the divisions between grades.

For the Florida hays (Fig. 7) many samples were in Grade 5 according to both predicted and actual DDMI. However, there were a number of discrepancies in which predicted grades were lower than actual grades. Eight samples of Suwannee bermudagrass and Pangola digitgrass were in Grades 2 and 3 according to actual DDMI, but no predicted grades were above Grade 4. In addition, six hays in Grades 2, 3, or 4 according to actual DDMI were predicted to be in Grade 5. Similar results were obtained with the Louisiana hays (Fig. 8). Although only 12 samples were in Grade 5 according to actual DDMI, 34 were predicted to be in Grade 5. As in the Florida hays, no Louisiana hays were predicted to be above Grade 4 although 25 of 51 hays were in Grades 1, 2, or 3 according to actual DDMI. In addition, there was much less variation in predicted than in actual DDMI values.

CONCLUSIONS

1. The proposed AFGC hay quality standards are based upon a sound concept: voluntary intake of digestible dry matter (or digestible energy).

2. The equations proposed by AFGC for prediction of dry matter digestibility and intake are generally unacceptable for tropical grasses, especially bermudagrass:

    a. digestibility is overestimated.
    b. intake is underestimated.
    c. ADF and NDF are often not closely related to digestibility and intake, respectively.

3. For tropical grasses, predicted DDMI and hay grades based on AFGC equations do not vary as much as do actual *in vivo* DDMI and grades, and the quality of higher-quality hays is underestimated by AFGC predictions.

4. More rational, and perhaps complex, models are necessary in order to apply the AFGC hay grades to tropical grasses in the South.

ACKNOWLEDGEMENT

Data on the Louisiana forages were provided by Dr. Billy D. Nelson, Dairy Nutrition, Southeast Louisiana Dairy and Pasture Experiment Station, Louisiana State University, P. O. Drawer 567, Franklinton, LA 70438.

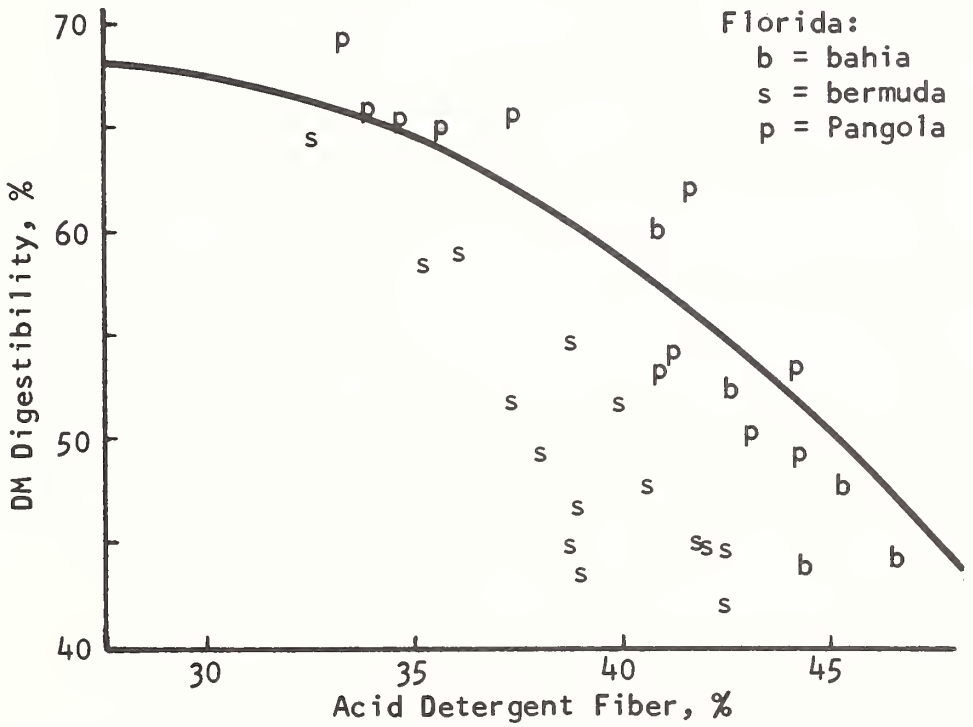

FIGURE 1.--Relationship between dry matter (DM) digestibility and acid detergent fiber of Florida Pensacola bahiagrass, Suwannee bermudagrass and Pangola digitgrass (solid line represents predicted values based on AFGC equations).

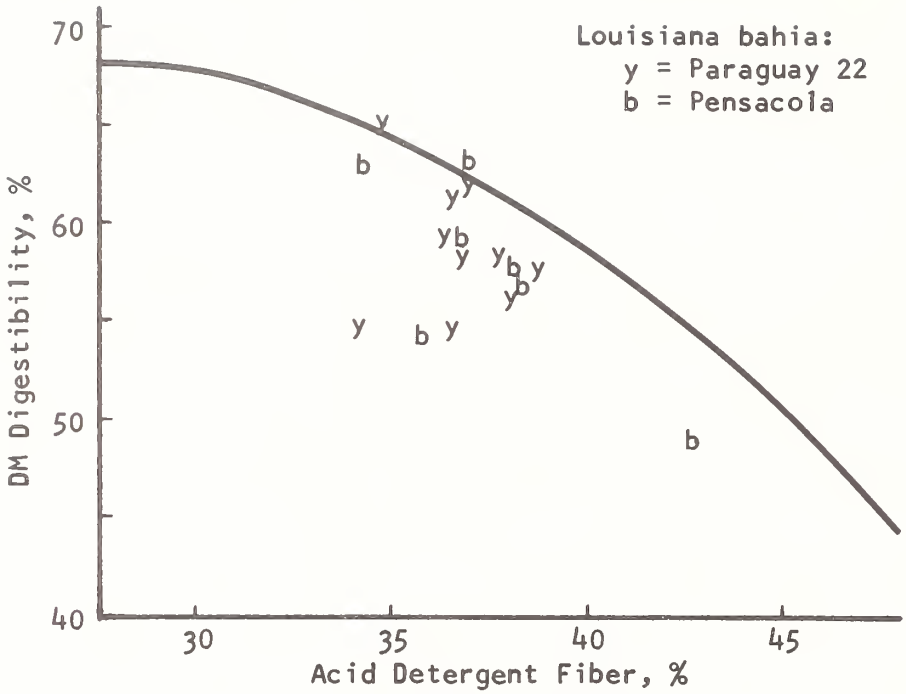

FIGURE 2.--Relationship between dry matter (DM) digestibility and acid detergent fiber of Louisiana bahiagrasses (solid line represents predicted values based on AFGC equations).

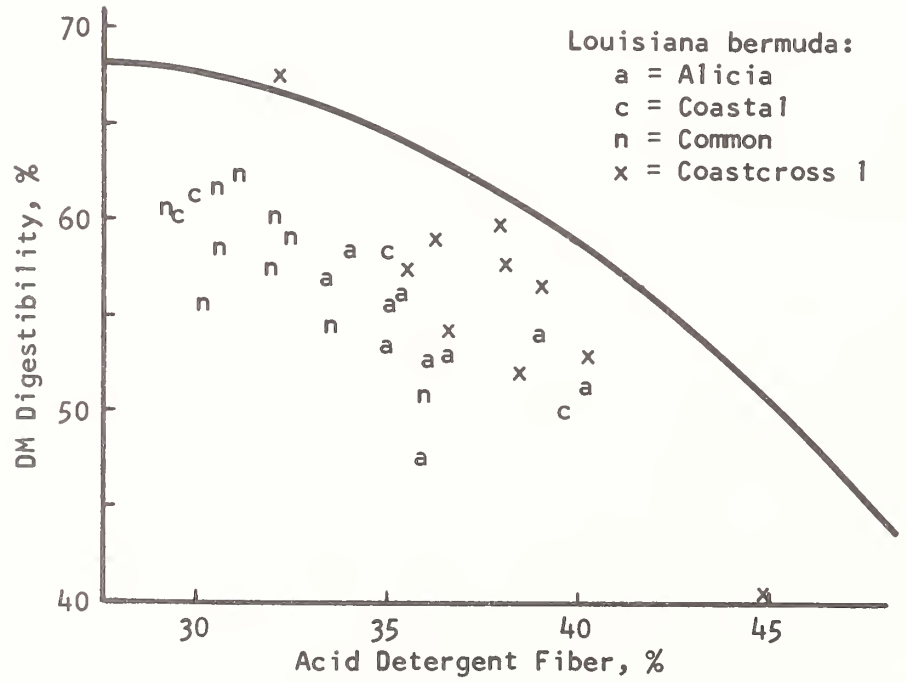

FIGURE 3.--Relationship between dry matter (DM) digestibility and acid detergent fiber of Louisiana bermudagrasses (solid line represents predicted values based on AFGC equations).

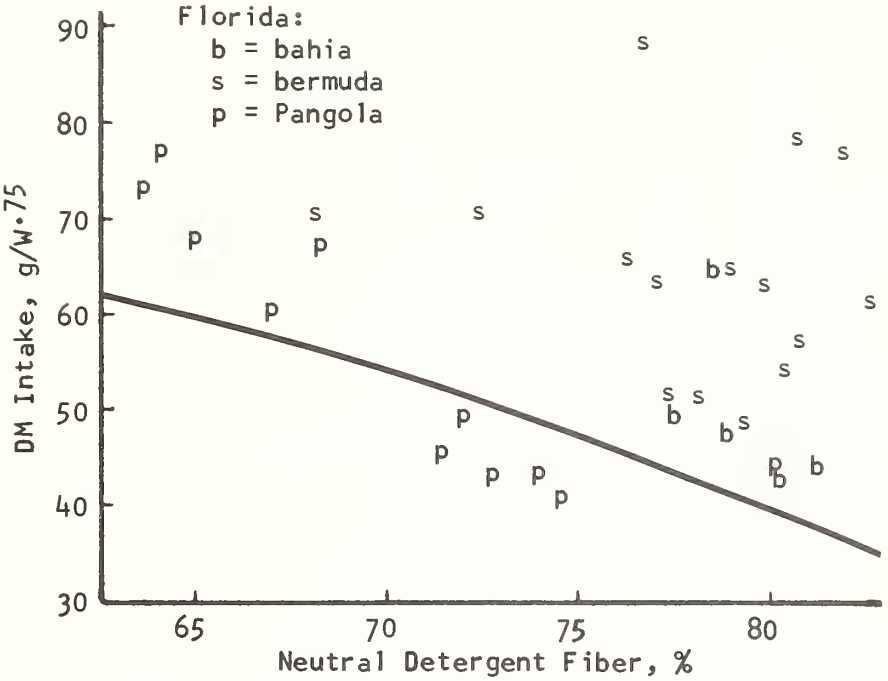

FIGURE 4.--Relationship between dry matter (DM) intake and neutral detergent fiber of Florida Pensacola bahiagrass, Suwannee bermudagrass and Pangola digitgrass (solid line represents predicted values based on AFGC equations).

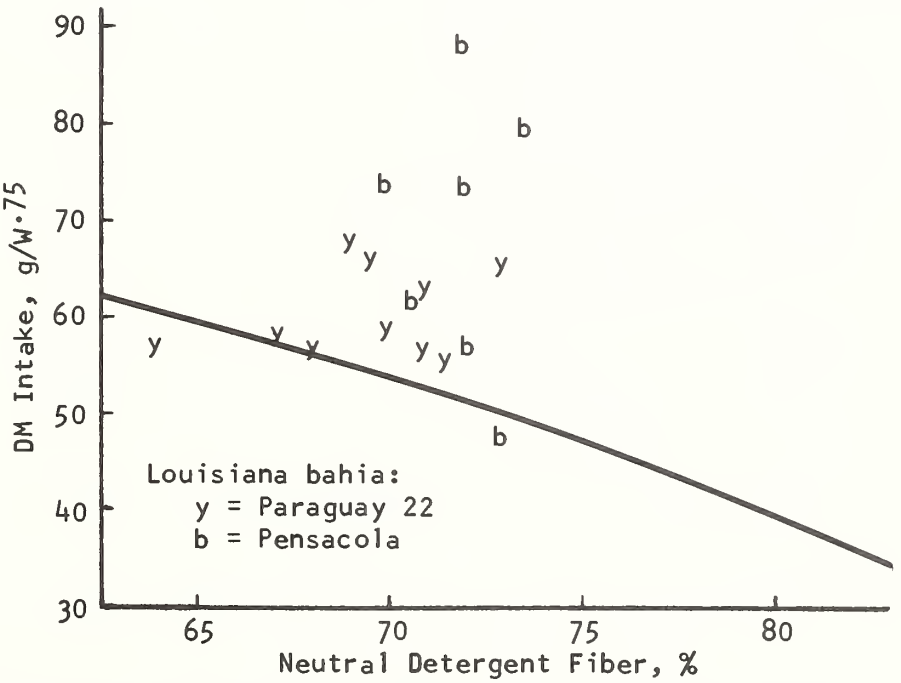

FIGURE 5.--Relationship between dry matter (DM) intake and neutral detergent fiber of Louisiana bahiagrasses (solid line represents predicted values based on AFGC equations).

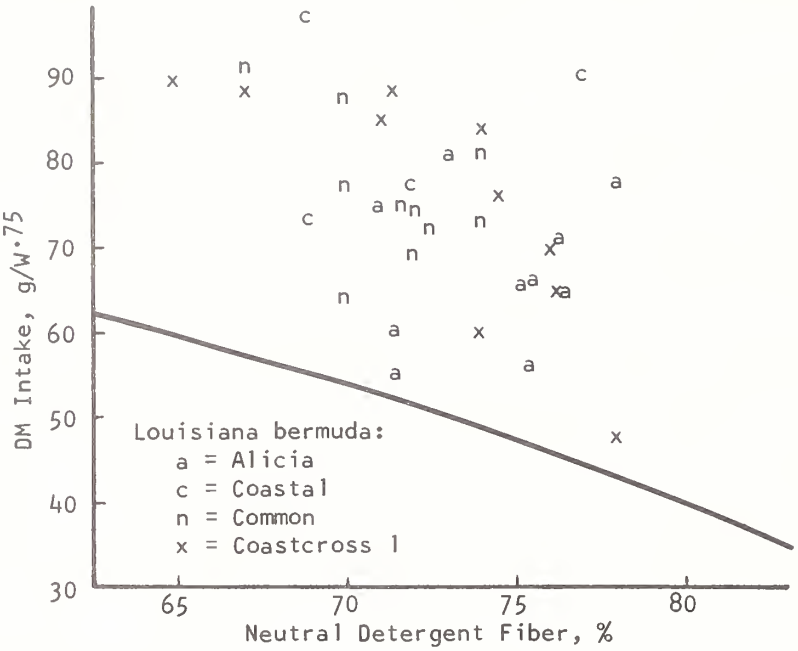

FIGURE 6.--Relationship between dry matter (DM) intake and neutral detergent fiber of Louisiana bermudagrasses (solid line represents predicted values based on AFGC equations).

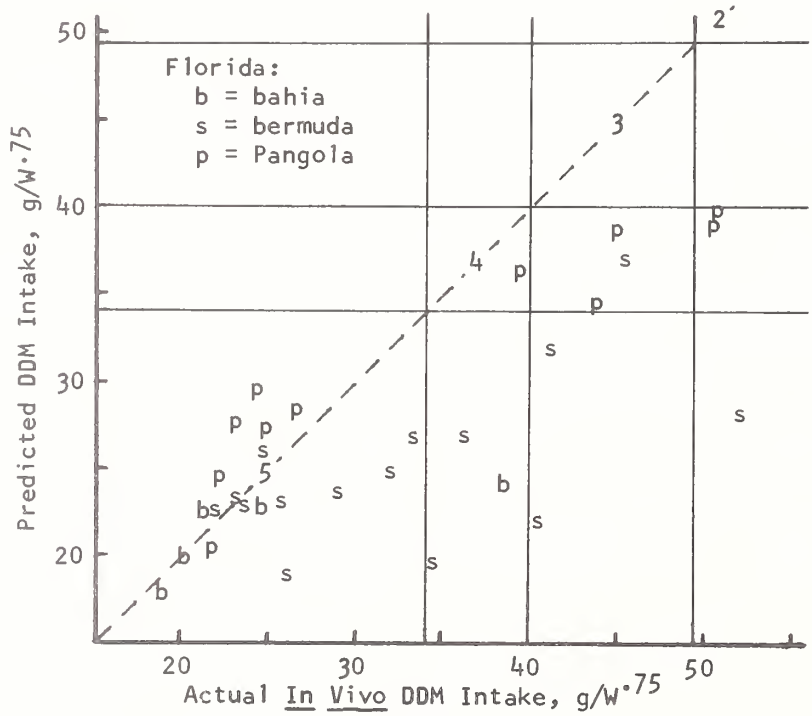

FIGURE 7.--Comparison of predicted with actual digestible dry matter (DDM) intakes of Florida Pensacola bahiagrass, Suwannee bermudagrass and Pangola digitgrass (vertical and horizontal lines indicate divisions between grades).

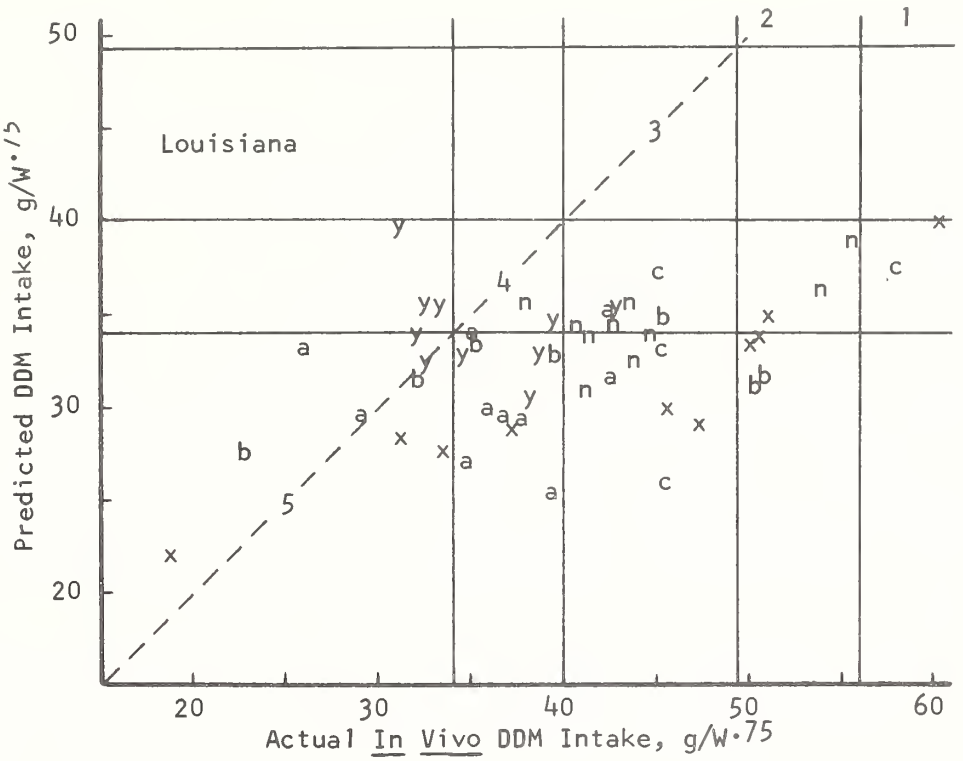

FIGURE 8.--Comparison of predicted with actual digestible dry matter (DDM) intakes of Louisiana forages; a = Alicia bermudagrass, b = Pensacola bahiagrass, c = Coastal bermudagrass, n = Common bermudagrass, x = Coastcross I bermudagrass and y = Paraguay 22 bahiagrass (vertical and horizontal lines indicate divisions between grades).

STORAGE AND PRESERVATION OF FORAGE

By J. Kenneth Evans

Introduction

Every year farmers in the humid Southeastern United States need stored feed during periods when low temperatures and/or low moisture limit plant growth. Since 70-80% of the total seasonal production of some cool season species may be made prior to June 15, surplusses produced during this period must be harvested and preserved for feeding during periods of slow or no growth.

Harvesting can usually be accomplished, but preservation is more difficult. Drying conditions are generally poor. Soil moisture and humidity are high and rains are frequent. Another complicating factor is heavy farm work loads in other crops at the time first forage harvests should be made. This usually results in forages waiting until other jobs are done and the result is late harvested, low quality forages. Methods of handling which reduce the necessary drying time, speed up packaging and storage and reduce the farm labor load are all desirable.

Reduce Drying Time

Reducing necessary drying time would reduce the probability of getting hay wet after cutting. Drying time can be reduced by either getting water out faster or storing at higher moisture contents. Dehydration results in rapid water removal and has been used some. It is not likely to be practically applicable to small farm operations and energy procurement problems may make dehydration even less attractive. Hay conditioners also speed water loss from forage, causing stems to dry, at nearer the same rate as leaves. This can result in less leaf loss and higher quality hay. But even conditioned hay often gets rained on before it is cured enough to bale. The other approach to reducing drying time is to store forage at higher moisture content, thereby reducing probability of rain damage.

Silage and haylage are probably the best alternatives, but very few farmers make silage from cool season grasses and legumes. Most silage is made from corn and small grain by dairymen. In the past few years there has been an increase in alfalfa silage, but the majority of forages is stored as hay. Why don't we make more silage?

Back in the 1950's some farmers tried making long "grass" silage and failed. Butyric acid fermentation and the associated horrible odor made most farmers shy away from grass silage. Also, many farmers feel they cannot economically justify capitalization of a silage system.

Bad experience and expense aren't the only reasons. Several other possible reasons are: (1) Many part-time farmers lack either the time or farm experience needed to convert to silage; (2) beef cattle are the major consumers of stored forage and the majority of beef herds are small, not only in numbers per herd, but also in their contribution to farm income; and (3) beef cattle are considered by many as "scavengers" to utilize poor quality feed. Hay will probably continue to be the major stored feed for some years.

Can hay be stored at high moisture content? Research on hay preservatives is underway at several institutions. Ammonium isobutyrate, propionic acid, acetic acid, and anhydrous ammonia have each been found to give good control of mold growth and have reduced heating under certain conditions (1,2). Variability in results can possibly be attributed to the lack of a system which gives a uniform application of the chemical to the hay. Anhydrous ammonia looks extremely good in research at Purdue University, not only for mold inhibition and reduced heating, but also for increased N content. Application to large quantities of hay is impossible at this time, but Vic Lechtenberg feels he may have a system that will work this year.

Preservatives that will permit baling (without spoilage) at 30-40% moisture, will make it possible to bale hay after a 24 hour curing period. If they are practical and economical to use with the hay equipment now on farms, they will be rapidly adopted by farmers.

Speedy Packaging With Reduced Labor

There is fairly general agreement that big bales or stacks cannot be packaged at moisture contents higher than small rectangular bales. Some even say the hay must be drier if it is to retain quality in the big packages. Big packages do permit large quantities of hay to be packaged fast and with a lower labor requirement per ton than even a mechanized small bale pick-up system (3,4). Two other factors also help account for the wide farmer adoption of these big package systems: (1) The hay is ready for a rain as soon as it is baled or stacked and can be moved to a storage area when the work load is less demanding; and (2) feeding is easier and can be done with less labor.

Even though large package systems are less labor demanding than small bale systems, the losses in storage and at feeding can be great. In an Auburn University comparison of a small conventional bale system and a stack system, animal gains were more expensive for the stack system even at 2000 tons per year volume (5). This was primarily due to the extremely high feeding losses when stacks were fed without racks to keep animals from getting on the hay. Outside storage usually does result in some losses in total digestible dry matter (3,5,6). These losses as well as feeding losses should be weighed against the time and labor savings by each individual farmer.

Research Needs

There are three areas of research which need attention:

1. Big package storage of legumes and losses in storage - Most of the storage research has been done on johnsongrass (5), bermudagrass (3), and fescue (3,6). Although a small amount of work has been done on alfalfa in Oklahoma and Indiana (3,6), there are very little quantitative data on red clover and other legume and legume-grass mixtures;

2. Chemical Preservatives - Successful chemical preservation of high moisture hay has been accomplished in small quantities. Now we need practical methods of getting uniform treatment on a field basis;

3. Unconventional silage systems - Some wildly imaginative thought is needed on a method whereby silage could be made from forage crops in the spring, using the equipment which farmers presently own. For example, one brand of the big balers will physically handle extremely high moisture forage. Would it be possible to bale forage at 65-70% moisture, wrap the bales in black plastic, seal and get acceptable ensilage?

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POISONOUS PLANTS IN PASTURES AND ANIMAL RESPONSE

By Agee M. Wiggins, D.V.M., M.S.

Poisonous plants are a very real economic factor in raising livestock in the south eastern United States. It is estimated that there are over 400 poisonous plants in the United States. Of course all are not in the Southeast but we have our share. Many factors are involved in whether an animal is poisoned and one of the largest factors is hunger. It is fortunate that most poisonous plants are not very palatable. However when an animal is hungry enough, it will eat almost anything.

Most of you are familiar with the pasture plants that are poisonous on occasion, (Fescue, Bermuda grass). This morning I would like to mention a few that are not true pasture plants but rather are weeds or native growths, (Bracken fern, mountain laurel, cherry, oak, etc.) These plants account for large numbers of animals being poisoned each year in our locality.

Brackenfern (Pteridium aquilinum (L.)

Brackenfern is nationwide in distribution. This plant causes poisoning in most species of animals but is seen most often in cattle. It produces two syndromes dependent upon the specie of animal. All simple stomach animals are affected due to a lack of thiamine; there is a thiaminase present in the plant.(1) This, however, is not the reason for poisoning in ruminants. In ruminants the toxic substance is not known, but the action of it is; it causes a destruction of the bone marrow of animals. Large quantities of the plant are required in order for it to cause poisoning. In other words it requires continual browsing for clinical signs to develop. I will not discuss the toxicity in simple stomach animals because it is relatively rare. However, in cattle the condition is rather common and I would like to mention a few things in that regard. There have been feeding experiments to cattle that would indicate that it may require a hundred pounds or so for the bracken to cause poisoning. (2) However, in some instances that I have observed it would seem as though the condition could develop on quantities less than this. It is poisonous in the green growing stage and in hay and all parts of the plant are poisonous; in fact, the underground rhizomes are most toxic. (3) The destruction of bone marrow in animals results in a deficiency of all of the cells that are formed there, such as the red blood cells, the platelets, and all white cells except lymphocytes. This basically is the reason for the disease in the animal. In addition to the lack of red and white cells there is also an excess of heparin. The lack of blood platelets and the excess of heparin results in a rather severe hemorrhagic syndrome in ruminants. The clinical signs in poisoned ruminants are varied but most of them are associated with the hemorrhagic syndrome. There is an elevated temperature. This is probably due to bacterial growth in the animal's body that takes

place as a result of the lack of white cell activity. Temperatures of 104 to 106 are not uncommon. The other clinical signs that are observed include hemorrhages from the nose, or epistaxis, hemorrhage in the feces, anorexia, petecheal hemorrhages of the mucous membranes, and in some instances hematuria. Fly bites or insect bites usually result in continual bleeding from the bite sites. Diagnosis is based upon history and clinical signs coupled with lowered platelet counts and an abnormal blood picture. The blood will have lowered red cell counts, lowered white cell counts, and in the differential a marked relative increase in lymphocytes at the expense of the other white cells. Postmortem lesions include a generalized hemorrhagic syndrome with free blood in the lumen of the intestine, ulcerations of the stomach, and ecchymotic and petechial hemorrhages of the subcutaneous tissues. In some instances one may see tumors in the bladder; this is associated with a carcinogenic portion of the toxin of brackenfern. (4) Treatment is not very satisfactory but should be attempted and consists of whole blood transfusions, antibiotics, and intravenous injections of protamine sulfate.

Mountain Laurel (Kalmia latifolia(L.)

Mountain laurel is one of the plants in our area that results in poisoning of cattle and goats quite often. This plant ordinarily is not consumed except when there is lack of other food. Under those circumstances cattle and goats will browse the plant. The toxicity of the plant is quite high, in some instances and will result in death if sufficient quantities are consumed. Some recent work done would indicate that there is a seasonal degree of toxicity in the plant and that females are probably more susceptible than males. This work was done in rats but probably would apply to other species of animals. (5) The clinical signs of the disease develop shortly after consumption, usually within a matter of hours. The course of the disease depends upon the quantity consumed will run anywhere from a few hours to several days. There are no real diagnostic signs of laurel poisoning in cattle. The diagnosis is usually presumptive and based on history and finding browsed plants in the pasture where the animals have died. The animals show repeated eruption, swallowing and grinding of the teeth. There usually is excessive salivation, and in some instances bloat. Vomiting has been described as a prominent sign in animals, but has been observed by the author only in goats. Cattle apparently do not vomit. Abdominal pain, nasal discharge are also observed. There is increased intestinal motility that can be heard by auscultation. The animal gradually weakens, becomes ataxic and eventually postrate. Death is considered to be due to circulatory collapse. Postmortem lesions reveal gastrointestinal irritation and nephrosis, the nephrosis being due in part to the passage of the unchanged toxin in the urine. There is no satisfactory treatment for laurel poisoning in animals. Best results have occurred following the oral administration of mineral oil and intravenous administration of calcium borogluconate.

Night Shade Family
Black Nightshade (Solanum nigrum (L.) and Horse Nettle (Solanum carolinense(L)

These two plants have been responsible for deaths in animals in our practice area. The black nightshade usually is consumed as a green-growing plant, and Horse Nettle may be consumed as a green plant or most often as a result

of it having been incorporated into hay. The Solanum grouping has both an alkaloid and a glycoside poison. The alkaloidal portion is referred to as solanidine and the glycocidal portion is referred to as solanose. (6) The ripe berries of the black nightshade are said not to be poisonous; they are only poisonous when they are green. The berries of the horse nettle are most poisonous when they are ripe or yellow. The toxin results in one of two syndromes in animals; one is a severe gastroenteritis associated with the glycocidal portion of the plant, and the other is a neurological syndrome associated with the alkaloidal portion of the plant. The alkaloid produces drowsiness, salivation, dyspnea, trembling, progressive weakness of paralysis, prostration and unconsciousness. The gastrointestinal part or the glycocidal part produces gastric irritation that is characterized by nausia, abdominal pain and diarrhea with hemorrhage. The postmortem lesions of these animals can vary from none to severe involvement of the intestinal track. The alkaloidal portion, which is characteristic of most alkaloids, does not leave any gross pathological findings. The glycosidal portion, however, results in intestinal irritation with ulcerations and hemorrhage of the intestinal mucosa. In some instances there have been ulcerations of the mucosa of the esophagus and pharynx. There is no specific treatment. The important thing is to recognize the condition and to remove the animal from the source. Treatment that has been suggested include tannic acid and charcoal and protectives such as bismuth and mineral oil. The use of physostigmine or pilocarpine has been suggested for the treatment of nightshade poisoning.

Cyanide poisoning

Animals may be poisoned from a wide variety of cyanogenic plants. The ones most commonly involved are the sorghum plants. However there are several species of woody plants capable of causing poisoning. Among these are the Prunus species (i.e. Wild Cherry, Cherry laurel). Animals usually do not eat these except when the plants are cut down or are broken down by wind or logging. In the case of the Cherry laurel, pruning is the usual way the animals get the plants.

These plants are very toxic containing 200-300 mg. HCN/100gm of green leaves. The estimated MLD is approximately 20 mg/100gm of green leaves. The action of cyanide on the animal is tissue asphyxiation at the cellular level. The blood can transport O_2 from the lungs but the body tissues can't take it up. Thus we have suffocation. The animal responds to this with the clinical signs of gasping for breath, muscle twitching, staggering, convulsions and finally coma and death. Diagnosis can be based on clinical signs or laboratory evaluation of stomach contents. There are no postmortem lesions. Treatment - Sodium thiosulfate and Sodium nitrite or Methylene blue and dextrose.

Oaks (Quercus species)

In the spring the blossoms, buds, and young leaves of the oak are very attractive and palatable to cattle. This is true even though the cattle are well fed. Acorns are toxic in the fall and winter.

The toxic substance in oak and acorns is a gallotannin. (7) The blossoms, buds, and young leaves contain 14 to 18 percent of gallotannins on a dry weight basis. This content gradually reduces as the leaves mature and is only about 4 percent by late summer.

Oak poisoning is the number one problem of cattle in some parts of the

United States. It is estimated in Texas that this one plant causes more than $10,000,000 annual loss. The signs of oak poisoning are emaciation, edema, constipation or diarrhea with mucous and blood in the feces. The animals are drawn, have a rough haircoat and a dry nose, a bloody discharge may be running from the nose, lesions or gastroenteritis with degeneration of the epithelial lining, and edema of the intestinal walls. In some cases the lining of the esophagus has been eroded and a large percent is absent. The kidneys are swollen, light in color, and often contain petechial hemorrhages in the cortex. There is considerable edema associated with the entire carcass, especially around the kidneys. There may be large quantities of acitic fluid in the abdominal and thoracic cavity. It has been reported that there is a diagnostic microscopic lesion occurring in the kidneys. It has been described as the presence in some of the proximal convoluted and ascending tubules of a red-staining mass of solid material. This solid material occupies the area of the lumen and replaces the epithelium of the tubules. (8) Blood urea nitrogen is always elevated in oak poisoning and usually increases up to 100 to 500 mg/100 ml. An additional test can be run which determines the tannin level of the blood serum. Losses can be prevented in livestock likely to be poisoned by oak by fortifying the ration with calcium hydroxide.

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PASTURE WEED PROBLEMS AND APPROACHES USED IN MISSISSIPPI

By Vance H. Watson and Hiram D. Palmertree

With today's land prices, interest rates, and energy restrictions, we believe that a well designed pasture weed control program may be the key to profit or loss in beef cattle grazing programs. In Mississippi, the value of livestock and their products has increased several fold in the last twenty years. We have made good progress but the challenge of the future looks even more promising. For example, only 20 percent of our five million acres of pastures are maintained in improved grasses and legumes, only 10 percent are fertilized properly, and less than five percent receive some form of weed control.

We divide our pasture weed problems into three categories: (1) established perennial grass pastures with broadleaf and/or grassy weeds, (2) established grass-legume pastures with broadleaf and/or grassy weeds and (3) newly planted grass, legume, or grass-legume pastures. With the spectrum of herbicides cleared for use in pastures, the broadleaf weed problems in category 1 can be easily controlled. However, as use of clovers and other legumes becomes more widespread, we expect the broadleaf weed problems in category 2 to increase. In addition, several phenoxy tolerant broadleaf species have been increasing rapidly in the past few years, but we feel that they can be abated with stronger educational emphasis on choices of herbicides available. With the exception of smutgrass (Sporobolus poiretii) most producers treat the grassy weeds in category 1 and 2 as grazable herbage and feel that a primary effort to specifically control those species is usually not economical in a beef program. Weed pressures generated in category 3 probably cause the greatest concern and loss of production in new seedings. A list of the primary target species for the specific categories are presented in Tables 1, 2 and 3.

Our approach to pasture weed control has been to consider that all of our pasture acreage has some degree of weed pressure, and that it takes as much or more fertilizer to grow a pound of weeds as it does desirable forage. For example, three common pasture weeds such as pigweed, smartweed, and ragweed have been shown to accumulate approximately twice as much nitrogen, 1.6 times as much phosphorus, and 3.5 times as much potassium as a desirable forage plant such as corn. We initiated two experiments in 1975 to place a dollar value on pasture weed control in a typical pasture situation.

The trials were conducted on weed infested bahiagrass in Jefferson and Pearl River Counties. Heavy pressures of 2, 4-D tolerant weeds existed (mainly cypressweed, smartweed, horsenettle, prickly sida, and blue vervain). The Jefferson County experiment had a heavier weed infestation and a thinner

TABLE 1.--Primary broadleaf weed species in established grass and grass-legume pastures in Mississippi-1976

Common Name	Scientific Name
Redroot pigweed	*Amaranthus retroflexus*
Lambsquarter	*Chenopodium album*
Common yarrow	*Achillea millefolium*
Common ragweed	*Ambrosia artemisiifolia*
Mayweed	*Athemis cotula*
Horseweed	*Erigerron canadensis*
Bitter sneezeweed	*Helenium amarum*
Goldenrod	*Solidago sp.*
Woolly croton	*Croton capitatus*
Virginia copperleaf	*Acalypha virginica*
Curly dock	*Rumex crispus*
Buttercup	*Ranunculus sp.*
Blue vervain	*Verbena hastata*
Prickly sida	*Sida spinosa*
Horsenettle	*Solanum carolinense*
Smartweed	*Polygonum pensylvanicum*
Thistle	*Sonchus sp.*
Dogfennel	*Eupatorium capillifolium*

TABLE 2.--Primary grassy weed species in established grass and grass-legume pastures in Mississippi

Common Name	Scientific Name
Broomsedge	*Andropogon virginicus*
Smutgrass	*Sporobolus poiretii*
Foxtail	*Setaria sp.*
Little Barley	*Hordeum pusilluum*
Goosegrass	*Eleusine indica*
Barnyardgrass	*Echinochloa crusgalli*
Broadleaf Signalgrass	*Brachiaria platyphylla*

sod of bahiagrass than did the Pearl River County experiment. Banvel* (1.0 pint/acre) and Weedmaster* (1.5 pints/acre) were applied broadcast in May and data were taken 75 days later. No fertilizer was applied. A check plot that received no chemical weed control was used in each experiment as a comparison. Yield data collected are shown in Table 4.

From Table 4 we see that removing the weed competition resulted in an increase in bahiagrass production ranging from 470 percent to 698 percent. If a market value of $20 per ton were placed on the bahiagrass produced, ($20 was approximately the cost of grass production in 1976, not including harvesting cost), the value of weed control would be as outlined in Table 5.

Returns due to weed control ranged from $23.49 per acre to a high of $44.08 per acre.

What about quality of the bahiagrass? How was it affected by controlling the weeds? Data in Table 6 show that weed control reduced the lignin content from a high of 13.2 to a low of 5.9 percent. The digestible dry matter increased with weed control from a low of 43.1 percent without weed control to a high of 58 percent. This increase in quality could be the difference in several pounds of digestible dry matter per ton of hay or grazing.

The percentage of crude protein in the bahiagrass was essentially the same for the check and sprayed plots. However, if the increased production of desirable forage resulting from weed removal is considered, the influence of spraying on the value of protein produced ranged from nearly $38 per acre to nearly $97 per acre, depending upon the treatment and location.

Weed control resulted in a higher quality forage as well as tremendous increases in yield, and we feel that it is an integral part of any successful beef cattle program.

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*Banvel (dicamba) and Weedmaster (3/4 lb. 2,4-D + 1/4 lb. dicamba/qt.) are tradenames of products of Velsicol Corporation; both materials are recommended by the Mississippi Weed Science Committee for pasture weed control.

TABLE 3.--Primary broadleaf and grassy weed species in new seedings of grass, legume, or grass-legume pastures in Mississippi

Common Name	Scientific Name
Carolina geranium	*Geranium carolinianum*
Shepherds purse	*Capsella bursa-pastorius*
Virginia pepperweed	*Lepidium virginicum*
Morningglory	*Ipomea sp.*
Chickweed	*Stellaria media*
Henbit	*Lamium amplexicaule*
Crabgrass	*Digitaria sanguinalis*
Broadleaf signalgrass	*Brachiaria platyphylla*
Crowfootgrass	*Dactyloctenium aegyptium*
Texas panicum	*Panicum texanum*
Foxtail	*Setaria sp.*

TABLE 4.--Influence of Chemical Weed Control on Bahiagrass Production

Location	Chemical	Percent Broad-leaf weeds after 75 days	Dry Matter Yield lbs Bahiagrass/Ac.	Percent of Check
Jefferson Co.	Check	92.0	635	---
	Banvel	0.0	3005	473
	Weedmaster	0.0	2984	470
Pearl River Co.	Check	79.4	748	---
	Banvel	0.0	5156	698
	Weedmaster	2.0	4703	628

TABLE 5.--Value of Weed Control in Bahiagrass

Location	Chemical	lbs. Bahiagrass	Per Acre Value as Hay 1/	Increase Attributed to Spraying
Jefferson Co.	Check	635	6.35	------
	Banvel	3005	30.05	$23.70
	Weedmaster	2984	29.84	$23.49
Pearl River Co.	Check	748	7.48	------
	Banvel	5156	51.56	$44.08
	Weedmaster	4703	47.03	$39.55

1/ Based on a value of $20.00 per ton for unharvested forage.

TABLE 6.--Effect of Weed Control on the Quality of Bahiagrass

Location	Chemical	Percent Lignin	Percent Digestible Dry Matter
Jefferson Co.	Check	13.2	43.1
	Banvel	6.8	50.8
	Weedmaster	6.1	49.7
Pearl River Co.	Check	9.2	48.5
	Banvel	5.9	58.0
	Weedmaster	5.9	57.2

TABLE 7.--Effect of Weed Control on the Crude Protein Content of Bahiagrass forage

Location	Chemical	Crude Protein %	Crude Protein lbs./Ac[1] /	Crude Protein Value[2] /	Increase Attributed to Spraying
Jefferson Co.	Check	7.4	46.8	9.36	------
	Banvel	8.1	242.2	48.40	$39.04
	Weedmaster	7.9	235.1	47.02	$37.66
Pearl River Co.	Check	10.7	79.6	15.92	------
	Banvel	10.9	564.0	112.80	$96.88
	Weedmaster	10.4	491.0	98.18	$82.26

[1] /Protein yield calculated from D. M. yield X % crude protein.

[2] /Protein value assumed to be 20¢/lb. as this is the approximate cost of a pound of protein from cottonseed meal.

EFFECTS OF GRAZING MANAGEMENT ON A SMUTGRASS-BAHIAGRASS-WHITE CLOVER SWARD

By William R. Ocumpaugh

Smutgrass (*Sporobolus poiretii* (Roem. and Shult.) Hitch.) has become a serious threat to improved pastures of the southeastern states including Florida. A recent survey in Central and South Florida counties indicated that 75% of the improved pastures were infested with smutgrass and that the average level of infestation was 38%. Smutgrass is considered to be the most common and most troublesome weed in pasture in Florida (Table 1). The objectives of this experiment were to determine the effects of grazing pressure and rest period, at five levels each, on the botanical composition of a smutgrass-bahiagrass-white clover sward.

Mob grazing techniques were used to carry out the perscribed grazing pressures ranging from 500 to 3700 kg/ha residue after grazing. The length of rest period between grazing ranged from 0 (continuous grazing) to 56 days of rest.

Only one season of grazing has been completed, thus the results should be considered to be tentative. The preliminary results indicate that the length of rest has little effect on changes in botanical composition. However, the level of grazing pressure has shown significant differences in botanical composition following just one season of grazing. The smutgrass ground cover increased with time at the lower grazing pressures. In addition a slight decrease in smutgrass ground cover was observed at the highest grazing pressure and shorter rest periods. By October of the first season of grazing, white clover had become a significant part of the sward under heavy grazing pressures. By March, nearly 100% of the canopy cover of the heavy grazed pastures were clover, whereas almost no clover existed under the lightest grazing pressure treatments.

It should be pointed out that considerable weight losses were experienced on catttle that were forced to consume nearly all of the smutgrass in a pasture.

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Table 1. The ten most common and most troublesome weeds in pasture in Florida*

Most Common	Most Troublesome
Smutgrass	Smutgrass
Dogfennel	Dogfennel
Wax myrtle	Wax myrtle
Vaseygrass	Sandbur
Curly dock	Broomsedge
Torpedograss	Prickly pear
Broomsedge	Nutsedge
Horseweed	Torpedograss
Prickly pear	Curly dock
Nutsedge	Horseweed

*From January 1977 Southern Weed Science Society Research Report. Tables 8 and 26.

WEED PROBLEMS IN ALABAMA PASTURES

By C. S. Hoveland

The major weed problems in pastures are listed in order of importance:

Warm Season Perennial Grasses

1. Dogfennel (Eupatorium capillifolium)
2. Smutgrass (Sporobolus poiretti)
3. Broomsedge (Andropogon virginicus)
4. Wolftail (Carex cherokensis), Black Belt only.
5. Multiflora rose (Rosa multiflora)
6. Blessed thistle (Cnicus benedictus)
7. Horse nettle (Solanum carolinense)
8. Bitter sneezeweed (Helenium amarum)
9. Carolina geranium (Geranium carolinianum)
10. Henbit (Lamium amplexicaule)
11. Redroot pigweed (Amaranthus retroflexus), northern Ala.
12. Ragweed (Ambrosia artemisifolia), northern Ala.

Cool Season Perennial Grasses (Tall Fescue)

1. Broomsedge (Andropogon virginicus)

Cool Season Annuals

1. Curly dock (Rumex crispus)
2. Wild mustard (Brassica kaber)
3. Redroot pigweed (Amaranthus retroflexus)
4. Ragweed (Ambrosia artemisifolia)
5. Florida purslane (Richardia scabra), southern Alabama
6. Cutleaf evening primrose (Oenothera laciniata)
7. Carolina geranium (Geranium carolinianum)
8. Goosegrass (Eleusine indica), southern Alabama

MONENSIN - WHAT, HOW AND POTENTIAL ON PASTURE

Gerald W. Horn

Monensin is a monocarboxylic polyether antibiotic produced by Streptomyces cinnamonensis, and has been shown to exhibit moderate in vitro activity against gram-positive organisms and certain mycobacteria (Harvey and Hoehn, 1967). Monensin sodium is marketed as a feed additive (Rumensin[1]) for improved feed efficiency of "cattle being fed in confinement for slaughter". The approved feeding level of monensin for feedlot cattle is 5 to 30 g per ton of feed. Weight gains of feedlot cattle fed monensin may be unchanged, increased or decreased depending on the level at which monensin is fed (Raun et al., 1976). Studies relative to the effect of monensin on ruminal fermentation, performance of forage-fed cattle, feed efficiency of feedlot cattle, and carcass characteristics of cattle have been reported by Richardson et al. (1976), Potter et al. (1976), Raun et al. (1976), and Potter et al. (1976), respectively. The mechanism of action and potential of monensin for forage-fed cattle are discussed below.

Mechanism of Action

Although the mechanism of action of monensin is not completely understood, the improvement in feed efficiency of feedlot cattle is related to the shift that is effected by monensin in the production of ruminal volatile fatty acids (VFAs), increasing propionic acid and decreasing acetic and butyric acid concentrations (Richardson et al., 1976). The shift in VFA production decreases ruminal fermentation energy losses by decreasing (1) methane production (Hungate, 1966) and (2) heat of ruminal fermentation (Wolin, 1960), and increases the amount of dietary energy available to the animal.

Other actions of monensin may include:

1. Since greater quantities of ruminal propionic acid are produced in response to monensin, increased quantities should be available at the animal tissue level. Propionic acid may be utilized more efficiently by animal tissues than other VFAs due to a lower heat of metabolism (heat increment) and save energy. (Thornton and Owens, 1976)

2. Monensin may have a protein-sparing effect by (a) decreasing ruminal destruction of feed protein and/or amino acids by bacteria, and (b) decreasing the catabolism of gluconeogenic amino acids at the animal tissue level as a result of increased propionic acid.

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[1]Elanco Products Company, Indianapolis, Indiana.

TABLE 1. Effect of monensin on weight gain and feed efficiency of cattle fed high-forage rations in drylot or grazed on pasture.

Ration or Forage Type	Ration or Forage Protein Content (% of DM)	Weight Gain, lb/day				Reference
		Control	Monensin	Monensin Level[a]	% Change due to Monensin	
73% Forage sorghum silage						
Heifers - trial 1		1.46	1.57	200 mg	+ 7.5	Riley et al., 1976
Heifers - trial 2	12.4	1.95	2.04	200 mg	+ 4.6	
94% grd alfalfa hay or dehydrated alfalfa meal	17.0	2.07	2.49	30 ppm	+20.2	Dinius et al., 1976
75% Corn silage, grd high-moisture ensiled corn, SBM	11.8	2.52	2.49	300 mg	- 1.2	Gill et al., 1976
Orchardgrass, alfalfa, brome-grass, ladino clover						
pasture and greenchop		1.19	1.39	200 mg	+16.8	
greenchop		1.09	1.29	200 mg	+18.3	Potter et al., 1976
Native bluestem pasture		1.32	1.60	106 mg	21.2	Schwartz et al,1977
Short grass pasture-Northwestern Kansas[b]		1.86	2.12	100 mg	+14.0	Schwartz et al,1977
Bermudagrass pasture		0.92	1.12	200 mg	+21.7	Griffin et al.,1977
Bermudagrass pasture		1.24	1.72	100 mg	+38.7	Oliver, 1975
Bermudagrass hay		1.50	1.67	200 mg	+11.3	Utley et al., 1976
Meadow hay[c]	8.4	0.57	0.99	200 mg	+73.7	Turner et al., 1977
Fescue pasture, dry bermudagrass and limited white clovers						Apple, 1977
0-56 days		1.48	1.61	200 mg	+ 8.8	
56-112 days[d]		0.97	1.43	200 mg	+47.4	
Wheat-ryegrass pasture[e]		0.79	0.81	200 mg	+ 2.5	McCartor et al,1976
Wheat-ryegrass pasture		2.16	2.05	106 mg	- 5.1	DeMuth et al., 1976
Wheat pasture		0.66	0.70	36 mg	+ 6.1	Scott et al., 1977
Wheat pasture	30.0	1.67	1.23	200 mg	-26.3	Horn et al., 1977

	Feed/Gain			
	Control	Monensin	% Change due to Monensin	Reference
73% Forage sorghum silage				
Heifers - trial 1	8.85	7.82	-11.6	Riley et al., 1976
Heifers - trial 2	8.05	7.06	-12.3	
94% grd alfalfa hay or dehydrated alfalfa meal	11.4	9.1	-20.2	Dinius et al., 1976
75% Corn silage, grd high-moisture ensiled corn, SBM	7.40	6.82	- 7.8	Gill et al., 1976
Orchardgrass, alfalfa, bromegrass, ladino clover				
Pasture and Greenchop	-----	-----	-----	
Greenchop	13.92	11.91	-14.4	Potter et al., 1976
Native bluestem pasture	-----	-----	-----	Schwartz et al., 1977
Short grass pasture-Northwestern Kansas[b]	-----	-----	-----	Schwartz et al., 1977
Bermudagrass pasture	15.4	12.5	-18.8	Griffin et al., 1977
Bermudagrass pasture	-----	-----	-----	Oliver, 1975
Bermudagrass hay	-----	-----	-----	Utley et al., 1976
Meadow hay[c]	46.9	26.2	-44.1	Turner et al., 1977
Fescue pasture, dry bermudagrass and limited white clovers				Apple, 1977
0-56 days	-----	-----	-----	
56-112 days[d]	-----	-----	-----	
Wheat-ryegrass pasture[e]	-----	-----	-----	McCartor et al., 1976
Wheat-ryegrass pasture	-----	-----	-----	DeMuth et al., 1976
Wheat pasture	-----	-----	-----	Scott et al., 1977
Wheat pasture	-----	-----	-----	Horn et al., 1977

(a) Level (mg/head/day or ppm) at which greatest response was obtained. (b) One-third of cattle in each group were implanted with DES, and one-third of cattle in each group were implanted with ralgro. (c) Mature cows during gestation. (d) Due to shortage of pasture, cattle received primarily bermudagrass hay during last 56 days of trial. (e) Limit-grazed on wheat-ryegrass pasture 4 hr/day, 3 days/week for 67 days, and then 4 hr/day, 7 days/week for 90 days.

A reduction in ruminal destruction of protein would result in greater ruminal bypass of dietary protein, and would be expected to have a greater effect on performance for cattle fed lower versus higher protein-containing rations. This rationale is supported by the studies of Chalupa et al. (1976) on the effect of a deaminase inhibitor on performance of steers fed diets containing 30% roughage and either 11 or 14% protein. Owens (1977) has observed a 14% increase in non-ammonia nitrogen reaching the abomasum of steer fed a 85% concentrate, 17% protein ration containing 33 ppm of monensin. The response of feedlot cattle to monensin has generally been greater when fed low protein rations and has decreased or disappeared when fed higher protein levels (Owens and Thornton, 1977; Gates and Embry, 1976; Hanson and Klopfenstein, 1977).

3. Some discussion has centered on the suggestion that monensin may increase ruminal bacterial protein synthesis. Results of studies conducted by Lemenager (1977) in which ruminal dry matter and liquid turnover rates were decreased 44 and 31%, respectively, in steers fed harvested native winter range grass and 200 mg monensin do not support this suggestion. Similarly, the ruminal liquid turnover rate was decreased by 22% in steers fed a 63% corn diet and 200 mg of monensin/head/day (Lemenager, 1977).

Potential of Monensin for Forage-Fed Cattle

The potential of monensin for increasing performance of cattle on pasture, or fed high-forage rations in drylot is evidenced by many studies in which monensin has increased weight gains and feed efficiencies. The results of several studies relative to the effect of monensin on performance of cattle fed high-forage rations in drylot or grazed on pastures is shown in table 1. Weight gains and feed efficiencies of cattle fed high-forage diets in drylot have generally been improved. Large improvements in weight gains and feed efficiencies have been reported for cattle fed or grazed on low- to average-quality forages. The results of these studies indicate that monensin has a tremendous potential for increasing stocker performance where high-quality forage may not be available or cannot be maintained throughout the duration of stocker programs.

On the basis of a limited number of studies that have shown minimal or negative weight gain responses by stockers grazed on high-quality forages such as wheat and ryegrass mixtures or wheat, the potential of monensin for increasing weight gains appears questionable at this time. Wheat forage is high in crude protein with 17 to 33% of the total nitrogen being in the form of non-protein nitrogen (Johnson et al., 1974). Forage crude protein content and form of forage nitrogen (e.g., soluble nitrogen versus insoluble nitrogen and non-protein nitrogen versus protein nitrogen) may be important factors relative to the observed weight gain response to monensin of forage-fed cattle. Monensin (200 mg/head/day) increased daily gains 19.5 and 10.1%, respectively, of steers fed a ration consisting of a 60:40 ratio of corn silage to sodium hydroxide treated husklage and supplemented with brewers dried grains (low ruminal solubility) to result in rations that contained 10.5 and 12.5% protein. Daily gains were decreased 1.7 and 8.6%, respectively, for steers fed the same rations supplemented with urea in place of brewers dried grains (Hanson and Klopfenstein, 1977). Feed to gain ratios of the steers fed the BDG-

supplemented rations with 10.5% and 12.5% crude protein and the urea-supplemented rations with 10.5% and 12.5% crude protein were decreased 16.4 and 8.7% and increased 2.4 and 9.5%, respectively.

Additional studies are needed relative to the effect of monensin on forage intake and weight gains of cattle grazed on high-quality forages, and hence the efficiency of forage utilization. Preliminary results of studies in which wheat forage intake was measured by stockers grazed on wheat pasture and bolused with 200 mg monensin/head/day in gelatin capsules have not shown a depressing effect of monensin on wheat forage intake.

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IMPORTANCE OF RUMINAL PROTEIN DEGRADATION ON AMINO ACID AVAILABILITY

By H. E. Amos, J. J. Evans and D. Burdick

INTRODUCTION

The humid southeastern United States has the capacity to produce an abundant supply of high quality forage. When produced under ideal management systems this forage may routinely contain in excess of 13% crude protein. Biological values for forage protein which are equal to casein, beef muscle and soybean protein have been reported (Akeson and Stahman, 1965; Woodham, 1971). Unfortunately under most of our harvesting, storing and feeding procedures, forage protein may undergo considerable degradation with actual losses of amino acids available to the animal. In ruminants, forage protein undegoes considerable microbial transformation during passage through the ruminoreticulum. Hogan, et al., (1970), reported that intraruminal protein degradation and resynthesis by the microbial population modified the total amount of amino acids reaching the intestine but did little to alter the proportions of amino acids available to the animal. The objective of this report is to review some of the recent research we have conducted on these microbial transformations of forage protein during ruminoreticular fermentation, with particular emphasis on quantitating microbial protein, forage protein and amino acids which reach the lower gastrointestinal tract.

These studies were conducted in mature rumen and abomasum cannulated wethers fed an all Coastal bermudagrass (CBG) diet. The rate of passage of digesta from the ruminoreticulum into the abomasum was determined by using lignin to quantitate the solid digesta and polyethylene glycol to quantitate the liquid digesta. Abomasal samples were collected at various times after feeding and aliquots combined to provide a working sample representing the total digesta reaching the abomasum in a 24 hour period. The combined sample was analyzed for total crude protein (CP), ammonia, amino acids and microbial protein. Forage protein reaching the abomasum was calculated by subtracting microbial plus endogenous protein (Hogan and Phillipson, 1960) from the total protein recovered from the abomasal digesta.

Table 1 presents a comparison of the amino acid composition of CBG protein and rumen bacterial protein (RBP). The most noticeable difference between these two protein sources is the slightly greater content of total essential amino acids (37.03 vs. 34.24 g/100g CP for RBP and CBG protein, respectively) in RBP. The contents of lysine, threonine, isoleucine, phenylalanine and methionine plus cystine appear higher and histidine, arginine and leucine appear somewhat lower in RBP compared to CBG protein. Valine content of the two proteins is the same. Although there is some difference in the individual nonessential amino acids between the two proteins, total nonessential amino

TABLE 1.--A comparison of the amino acid composition of coastal bermudagrass and rumen bacterial protein

Amino Acid	Coastal Bermudagrass	Rumen Bacteria
	(g Amino Acid/100g Crude Protein)	
Lysine	4.14	6.12
Histidine	1.63	1.34
Arginine	3.92	3.50
Threonine	3.56	4.13
Valine	4.52	4.54
Isoleucine	3.72	4.37
Leucine	6.64	5.68
Phenylalanine	3.89	4.15
Methionine + Cystine	2.22	3.20
TOTAL	34.24	37.03
Aspartic acid	9.24	8.76
Serine	3.83	3.28
Glutamic acid	8.94	9.38
Proline	4.15	2.66
Glycine	4.07	4.10
Alanine	5.66	5.37
Tyrosine	2.84	4.00
TOTAL	38.73	37.55

TABLE 2.--Intake and recovery of total protein, microbial protein, and apparent forage protein from the abomasal digesta of wethers fed control or formaldehyde treated coastal bermudagrass hay[a] (trial 1)

Crude Protein Component	Formaldehyde level (%)			
	0	.5	1.0	1.5
	(g/day)			
Intake	113.5	114.9	112.9	113.1
Abomasal digesta[b]	103.5	104.6	123.2	137.0
As ammonia[c]	42.6	37.4	30.8	19.0
Nonammonia[b]	60.9	67.2	92.4	118.0
Microbial	43.4	41.2	39.1	34.5
Apparent forage[d]	5.0	13.5	40.8	71.4

[a]Adapted from the data of Amos et al., 1976a. J. Anim. Sci. 43:1300.

[b]Significant linear increase ($P<.005$).

[c]Significant linear decrease ($P<.10$).

[d]Calculated by subtracting microbial protein + endogenous protein (12.5g/day) from nonammonia crude protein.

acid content is essentially the same. Thus, any advantage in allowing CBG protein to undergo rumen fermentation would appear to be associated with the slight increases in essential amino acids; most of the increase can be accounted for by the increases in lysine and methionine plus cystine. However, as will be discussed later, rumen fermentation of the CBG protein can dramatically lower the total quantity of these and other amino acids available to the animal.

Table 2 presents the CP intake and various CP components recovered from the abomasal digesta of wethers fed 27-day old CBG hay which had been treated with 0, .5, 1.0 or 1.5% formaldehyde (trial 1). Intake of CP averaged 113.6 g/day for all treatments. Total and nonammonia CP recovered from the abomasal digesta increased linearly ($P<.005$) with increasing levels of formaldehyde. Ammonia decreased ($P<.10$) as the level of formaldehyde increased and accounted for 41.2% of the total abomasal CP at the 0% formaldehyde level but only 16.8% at the 1.5% treatment level. Microbial protein recovered from the abomasal digesta tended to decrease as the formaldehyde treatment level increased and was associated with a nonsignificant ($P>.10$) decrease in ruminal dry matter digestion (Amos et al., 1976a). The apparent CBG protein which reached the abomasum was 5.0, 13.5, 40.8 and 71.4 g/day for the 0, .5, 1.0 and 1.5% formaldehyde treatments, respectively. These data were calculated by subtracting total microbial protein per treatment plus 12.5g endogenous protein daily from total nonammonia CP and show that 4.4, 11.8, 36.1 and 63.1% of the CBG protein appeared to reach the abomasum with increasing levels of formaldehyde.

The following formula was used to estimate the maximum quantity of each respective amino acid which reached the abomasum from forage protein daily:

$$\text{Maximum Amino Acid from Forage Protein} = \text{Total of Respective Amino Acid Recovered at Abomasum (g/day)} - \left(\text{Microbial Protein (Recovered in } \left(\frac{\text{Abomasum (g/day)}}{100}\right)\right) \times \text{Percent of Respective Amino Acid in Microbial Protein}\right)$$

Results from these calculations and the average intake of each amino acid are shown in Table 3. The total of each respective amino acid reaching the abomasum daily may be found in Table 6 (see Amos et al., 1976a). In addition, it should also be emphasized that the term "maximum amino acid from forage protein" is used here because the above formula does not correct for the contribution of endogenous protein secretions to the total of a respective amino acid. These data clearly show that treating CBG protein with formaldehyde increases the quantity of each amino acid from the forage protein due to its not being degraded in the rumen. For example, an average of 4.9g of lysine was fed daily for each treatment and approximately 1.6, 1.8, 3.2 and 4.0g of this lysine reached the abomasum at the 0, .5, 1.0 and 1.5% formaldehyde treatment level, respectively. For the total essential amino acids, the data indicate that 11.9, 12.3, 24.2 and 28.7g reached the abomasum daily and indicate that a maximum of 29.4, 30.4, 59.9 and 71.0% of the essential amino acids consumed by the animal reached the abomasum at 0, .5, 1.0 and 1.5% formaldehyde treatment. Essentially the same results were noted with respect to the nonessential amino acids, 45.7g were consumed and 13.6, 16.6, 27.4 and 30.3g of nonessential amino acids were recovered from the abomasal digesta at 0, .5, 1.0 and 1.5% of formaldehyde, respectively. These latter data indicated that a maximum of 29.8, 36.3, 60.0 and 66.3% of the nonessential amino

TABLE 3.--Maximum recovery of amino acids from coastal bermudagrass protein in the abomasal digesta (trial 1, g/day)

Amino Acid[a]	Formaldehyde level (%)				
	Intake	.0	.5	1.0	1.5
Lysine	4.9	1.6	1.8	3.2	4.0
Histidine	1.9	.7	.8	1.2	1.3
Arginine	4.6	1.1	1.6	2.7	3.3
Threonine	4.2	1.6	1.7	2.7	3.4
Valine	5.4	1.8	1.1	3.4	3.8
Isoleucine	4.4	1.5	1.8	2.9	3.3
Leucine	7.8	1.9	3.0	5.2	5.8
Phenylalanine	4.5	1.0	.5	1.7	2.1
Methionine + Cystine	2.7	.7	.7	1.2	1.7
Total Essential	40.4	11.9	12.3	24.2	28.7
Aspartic Acid	10.9	2.9	3.9	7.6	7.5
Serine	4.5	1.7	2.0	2.9	3.3
Glutamic Acid	10.6	2.7	3.7	6.5	7.2
Proline	4.9	1.5	1.9	2.4	3.2
Glycine	4.8	1.6	1.7	2.4	3.2
Alanine	6.7	2.3	2.4	3.8	4.1
Tyrosine	3.3	.9	1.0	1.8	1.8
Total Nonessential	45.7	13.6	16.6	27.4	30.3
Total Essential + Nonessential	86.1	25.5	28.9	51.6	59.0

[a]There was a highly significant linear increase in each amino acid, total essential and total nonessential amino acids apparently derived from CBG protein with increasing formaldehyde level.

acids consumed reached the abomasum at the respective 0, .5, 1.0 and 1.5% formaldehyde treatment level.

The effect of CBG maturity (quality) on the daily quantities of total CP, ammonia, nonammonia CP, microbial protein, apparent forage protein and amino acids from CBG protein was determined in trial 2. The high quality CBG (HQ-CBG) was 21 days of age, field chopped, drum dehydrated, ground and pelleted and contained 16.4% CP and 4.8% acid detergent lignin (ADL) on a dry matter basis. The low quality CBG (LQ-CBG) was 56 days of age, partially sun cured, belt dehydrated, ground and pelleted and contained 9.3% CP and 7.3% ADL on a dry matter basis. The wethers consumed 725g and 675g of the HQ-CBG and LQ-CBG per day, respectively.

Table 4 presents a summary of the quantities of various abomasal CP components for the HQ- and LQ-CBG study. The wethers received 110.7 (HQ-CBG) and 58.3g of CP (LQ-CBG) daily (as fed basis). Total crude protein reaching the abomasum was 125.8 (HQ-CBG) and 97.2g (LQ-CBG) daily. When expressed as a percentage of intake, a higher percentage ($P<.05$) of the CP consumed reached the abomasum in wethers fed the LQ-CBG. This increase of approximately 39g CP (6.2g nitrogen) between the diet and abomasum (LQ-CBG) is indicative of the ruminant's ability to consume and recycle nitrogen when placed on a diet marginal in CP. With respect to the HQ-CBG diet, the wethers recycled approximately 15g of CP (2.4g nitrogen) through the rumen daily. These results, contrasted to trail 1, show the effect of artificial heat on CBG during the drying process. In trial 1, there was a loss of nitrogen (1.79g/day) between the diet and the abomasum in wethers fed sun cured hay. Also in trial 1, only about 4.4% of the CBG protein reached the abomasum (Table 1), while in trial 2,48.3g (43.6%) of the CP in the HQ-CBG diet reached the abomasum.

The effect of CBG maturity on the passage of CBG protein is quite noticeable (Table 4). These data show that 48.3g and 36.3g of the forage protein reached the abomasum daily and accounted for 43.6 and 62.3% of the forage protein consumed for the HQ-CBG and LQ-CBG, respectively. Nonammonia CP and ammonia were higher in the abomasal digesta in wethers fed the HQ-CBG and resulted from both increased CP intake as well as the increased synthesis of microbial protein with this diet. Microbial protein reaching the abomasum daily was higher on the HQ-CBG (38.8g) compared to the LQ-CBG (30.8g).

Table 5 gives the daily intakes and quantities of amino acids reaching the abomasum (trial 2). In wethers fed the HQ-CBG, the quantity of only the sulfur containing amino acids (methionine and cystine) were increased by rumen fermentation ($P<.01$). In wethers fed the LQ-CBG diet, the quantities of all individual essential amino acids (except arginine) and total essential amino acids were increased during passage of the diet to the abomasum ($P<.01$). The quantity of arginine increased between the diet and abomasum ($P<.05$). Total essential amino acids reaching the abomasum were increased approximately 2.3 times between the diet and the abomasum of wethers fed the LQ-CBG diet.

In wethers fed the HQ-CBG diet, total nonessential and individual nonessential amino acids (except serine and tyrosine) (Table 5) tended to decrease during passage of the diet to the abomasum. With respect to the LQ-CBG diet, there was a highly significant increase in individual and total nonessential amino acids, except proline, during passage of the diet through the ruminoreticulum to the abomasum. The data in Tables 4 and 5 indicate less destruction of the dietary amino acids from CBG protein of advanced age and more destruction and resynthesis of amino acids when diets composed of more immature CBG are fed. However, care must be exercised in making an overall

TABLE 4.--Intake and recovery of total protein, microbial protein and apparent forage protein from the abomasal digesta of wethers fed high and low quality coastal bermudagrass[a] (trial 2)

Crude Protein Component	High Quality	Low Quality
	(g/day)	
Intake	110.7	58.3
Abomasal digesta	125.8	97.2
Percent of intake	113.6[b]	166.7[c]
As ammonia	26.2	17.6
Nonammonia	99.6	79.6
Microbial	38.8	30.8
Apparent forage[d]	48.3	36.3

[a]Adapted from the data of Amos, et al., 1976b. J. Anim. Sci. 42:970.

[b,c]Means on the same line with different superscripts are different ($P<.05$).

[d]Calculated by subtracting microbial protein + endogenous protein (12.5g/day) from nonammonia crude protein.

Table 5.--Intake and recovery of amino acids from coastal bermudagrass protein in the abomasal digesta[a] (trial 2)

Amino Acid	High Quality		Low Quality	
	Diet	Abomasum	Diet	Abomasum
	(g/day)			
Lysine	4.6	5.7	2.0[b]	5.2[c]
Histidine	1.8	1.8	.4[b]	1.6[c]
Arginine	4.4	4.0	1.8[d]	3.1[e]
Threonine	3.9	4.6	1.7[b]	4.1[c]
Valine	5.0	5.1	2.1[b]	4.5[c]
Isoleucine	4.1	5.0	1.7[b]	3.8[c]
Leucine	7.3	7.9	2.9[b]	6.3[c]
Phenylalanine	4.2	4.7	1.6[b]	3.6[c]
Methionine + Cystine	2.0[b]	3.3[c]	.9[b]	3.2[c]
TOTAL	37.3	42.1	15.1[b]	35.4[c]
Aspartic acid	10.2	8.4	5.1[b]	7.8[c]
Serine	4.2	4.2	1.8[b]	3.7[c]
Glutamic acid	10.0	8.6	4.2[b]	8.2[c]
Proline	4.6	4.3	3.2	4.2
Glycine	4.5	4.7	2.2[b]	3.9[c]
Alanine	6.2	6.0	2.5[b]	5.0[c]
Tyrosine	3.1	3.7	2.1[b]	3.6[c]
TOTAL	42.8	39.9	21.1[b]	36.4[c]
GRAND TOTAL	80.1	82.0	46.2[b]	71.8[c]

[a]Adapted from the data of Amos, et al.,1976b. J. Anim. Sci. 42:970.

[b,c]Means on the same line within treatment with unlike superscripts differ significantly (P<.01).

[d,e]Means on the same line within treatment with unlike superscripts differ significantly (P<.05).

interpretation of the amino acid availability from the quantities reaching the abomasum in wethers fed the LQ-CBG diet. Sniffen and Jacobson (1975) have shown that quantites of amino acids absorbed from the intestines of steers fed an immature alfalfa hay diet was 5.3 times the quantity absorbed in steers fed a lower quality more mature diet. Thus the actual availability of amino acids from the forage protein escaping rumen degradation may have differed greatly in the study reported here.

SUMMARY

The stability of CBG protein to rumen microbial degradation was studied by using mature wethers as assay animals. Only 4.4% of CBG protein reached the abomasum in wethers fed a good quality CBG hay. However, forage protein reaching the abomasum increased to 11.8, 36.1 and 63.1% when the hay was treated with .5, 1.0 and 1.5% formaldehyde, respectively. Treating CBG with formaldehyde or artificially dehydrating the forage reduced nitrogen (CP) loss during passage of the diet to the abomasum. Amino acids reaching the abomasum were increased over two fold by rumen fermentation of a LQ-CBG diet; however, only methionine and cystine were increased by rumen fermentation of a high quality CBG diet.

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WEED PROBLEMS IN TEXAS PASTURES

By Gerald W. Evers

TAME PASTURES

Herbicides used on established pastures are 2,4-D, dicamba, simazine and atrazine with 2,4-D being used most widely. Simazine is also used in establishing bermudagrasses. Establishment of warm season perennial grasses is difficult, especially in high rainfall areas, due to weed competition. Paraquat, a fast acting contact herbicide, is being evaluated at Angleton for establishing dallisgrass (Paspalum dilatatum Poir.) and bahiagrass (Paspalum notatum Flugge). Grasses are planted and then paraquat is applied after the weeds come up but before the desired grasses emerge.

Smutgrass (Sporobolus indicus (L.) R. Br.), the major weed in improved pastures in Southeast Texas, is now being controlled with dalapon. Dalapon applied in the fall for smutgrass control also permits sod seeding of ryegrass for winter pasture. Herbicides are being evaluated for irrigated alfalfa in West Texas. Most of the alfalfa is marketed as cubes, but when the forage contains more than 10% weeds, the cubes will not hold together.

RANGE

Herbicides used for brush control in South and West Texas are 2,4,5-T and picloram or a mixture of the two. However none provide good control of mesquite (Prosopis spp.) the major brush problem in Texas. Tebuthiuron which is to be available soon, controls broadleaf weeds and some brush species including Western Honey Mesquite (Prosopis glandulosa var. torreyana (Benson) M. C. Johnston). Dicamba and 2,4-D are used to a limited extent on rangeland. Use of herbicides on Texas pastures and rangeland would increase with an increase in cattle prices.

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QUALITY OF LEGUME INOCULANTS AND HOW IT AFFECTS CLOVER PRODUCTION IN THE SOUTH

By Kenneth L. Smith

The symbiotic relationship between rhizobia and legumes has been known for nearly a century and many scientific advancements have been made since that time.

We have discovered that different clovers require different strains of rhizobia bacteria to produce maximum nodulation.

We have found that other bacteria compete with effective rhizobia for nodulation sites on the roots of legumes. We have found that soil temperature as well as storage temperature of the inoculant has an effect on how well legumes become inoculated and produce.

We have learned that excessive CO_2 in the root environment can inhibit inoculation.

We have learned that Ca, B, S, Mo, Fe, Cu and Co are needed for the nitrogen-fixing process as well as ample amounts of P and K for plant growth.

We have learned that a soil with a pH of greater than 6.0 is better for rhizobia than soils with lower pH values.

Yet, with all these scientific advancements, producers in the South are still having difficulty getting clovers properly established due to poor inoculation.

The objective of inoculation is to insure effective nodulation of the legume by providing adequate numbers of effective rhizobia at planting time and effective nodulation is considered achieved when the legume fixes enough nitrogen to meet its nutritional requirements during all stages of plant growth. It would be desirable to have a legume that was capable of fixing enough nitrogen to supply not only its own needs, but also the nitrogen requirement of a grass growing in a mixture with it. One day, our plant breeders and microbiologists will likely develop just such a plant. The problem at present is to develop better methods of growing existing species.

There have been conflicting data concerning the number of rhizobia required per seed in order to achieve effective nodulation. The numbers required will vary between species and environments. Date (2) reported that 100 rhizobia per clover seed were adequate under ideal conditions; however, Holland (3) concluded subclover should be inoculated with 7.5×10^4 rhizobia for effective nodulation in field conditions. Weaver used number of nodules on the tap root of soybeans as a measure of effective nodulation (7) and concluded that uninoculated soybeans planted in soil with less than 10^3 rhizobia per gram resulted in poor nodulation (8).

The Australians have a legume program that is far superior to the legume program in the United States, especially in the Southern United States. Much of this success can be attributed to their superior knowledge and appreciation of rhizobia. Australian farmers normally plant 10^3 rhizobia per seed and, if numbers are less than 300, the inoculum is considered unsatisfactory for sale.

One of the most complex and extensive educational efforts lies ahead if the Southern United States is to truly develop a legume system that works. Producers must be taught the importance of effective nodulation and how to determine if their legumes are effectively nodulated. There is a difference in methods of inoculation as indicated by the number of nodules found on the tap and lateral roots of Louisiana S-1 clover (Table 1) (6).

There is a positive correlation between numbers of nodules on the tap root and the dry matter production (Table 2) (6); however, such a correlation may not exist for protein content of clovers (Table 3) (6).

Most of the response to the inoculation methods can be attributed to rhizobia numbers and probably little to any superior ingredients of the inoculant preparation. Number of rhizobia per seed increases drastically due to better sticking agents (Table 4) (6).

Calcium carbonate pelleting offers some potential for increasing rhizobia numbers and clover performance (Table 5) (5); however, pelleting on the farm is laborious and discourages many farmers from planting clovers. The fact that seed planted in fumigated soil and inoculated at normal rates gave similar yields to $CaCO_3$-pelleted seed suggests that competitiveness and antagonistic organisms are causing some real problems.

Some seed companies have elected to pre-inoculate seed as a convenience to the farmer and, hopefully, increase clover performance and seed sales. Not all pre-inoculated seed are of good quality as reported by Purdue University (Table 6) (4).

Most clovers are fall planted in the Southern United States which means shipping seed and inoculant during the hot summer days in order to reach distributors in time for planting. This creates a problem that will not be overcome without a great deal of effort and understanding from everyone involved. The extent of damage to rhizobia by heat is exemplified in Table 7 (1).

This paper is presented in an attempt to point out some of the problems facing legume production in the South as they are related to inoculation. Hopefully, it will stimulate thinking among those concerned which will lead to better inoculation procedures with high quality products to enable the Southern United States to develop a reliable legume program.

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TABLE 1.--Inoculation methods of Louisiana S-1 clover

Treatment	Sampling Date					
Planted 11/15	3/10		4/1		4/17	
	T	L	T	L	T	L
O-I	1	5	2	4	5	34
P+W	1	8	2	12	9	46
P+GA	11	16	12	23	19	46
P+P	11	14	12	34	15	36

TABLE 2.--Dry matter production-Louisiana S-1

Treatment	Date		
	3/10	4/1	4/17
	-----g/30 cm row----		kg/ha
O-I	9.7	14	1593
P+W	5.9	13	1361
P+GA	10.9	29	2312
P+P	11.1	25	2582

TABLE 3.--Protein content-Louisiana S-1

Treatment	Date		
	3/10	4/17	6/5
O-I	10.1	18.3	20.3
P+W	11.2	16.4	18.1
P+GA	18.7	21.2	18.9
P+P	20.0	20.2	19.0

TABLE 4.--Estimated number rhizobia/seed at planting

Treatment	La. S-1	Arrowleaf
Peat	600	25
Pelinoc	3,000	3,000

TABLE 5.--Inoculation methods-Arrowleaf

	Dry Matter-kg/ha	
		Total
	3/11	5/11
$CaCO_3$ Pellet	980	7490
Soil Fumigation	584	7380
1 x Inoc.	330	4630
3 x Inoc.	760	6900
0 Inoc.	90	5260

TABLE 6.--Pre-inoculated seed

	Good	Fair	Unsatisfactory
Number	42	14	30
Percent	49	16	35

TABLE 7.--Million bacteria in peat

Week	45°F	72°F	90°F	106°F
0	794.4	794.4	794.4	794.4
2	794.4	794.4	199.5	28.8
4	794.4	562.4	56.2	56.6
6	794.4	316.3	44.7	4.5
8	794.4	125.9	31.6	3.2

SPFCIC EXTENSION WORK GROUP

SUMMARY OF FIVE MINUTE REPORTS BY STATES

SUBJECT: Status of Cool Season Grasses

by Donald M. Ball, Extension Agronomist, Auburn University

The Extension Work Group of the SPFCIC involved itself this year with a discussion of cool season grass species. This discussion centered around five-minute reports presented by representatives from the states which participate in the SPFCIC. Points discussed regarding each species mentioned included: (1) acreage; (2) grazing season; (3) varieties; (4) primary usage; and (5) rates of liming and fertilization.

As far as cool-season perennials are concerned, tall fescue is the predominant species used in the south. Most of the fescue acreage is in the more northerly states in the region, however. Florida is the only state having essentially no tall fescue acreage. The predominant tall fescue variety is "Kentucky 31", although some states (particularly the more northerly ones) also reported some acreage of "Alta", "Goar", "Fawn", and "Kenwell". In most states over 90% of the tall fescue acreage is devoted to providing grazing for beef cattle. It is also, however, utilized to some extent for providing grazing for dairy animals, and in some states to a very limited extent by swine, sheep, and horses. It was reported that in many instances tall fescue is used primarily for grazing, but with surplus growth being cut for hay. Most fescue hay produced is fed to beef animals. It was mentioned that while spring and fall grazing of fescue is reasonably good, summer quality declines badly - particularly in the more southern states.

Orchardgrass is the second most popular cool-season perennial grass species in the southern region. As with tall fescue, the largest acreage is in the northern part of the region. Most states have less than one-fourth as much acreage of orchardgrass as tall fescue which has a slightly longer growing season and somewhat higher production. The primary varieties grown are "Boone", "Potomac", and "Hallmark." There is also considerable acreage common orchardgrass grown in the region. Because of the relatively good quality of orchardgrass, a much higher percent of the acreage is used for diary animals, horses, sheep, and swine than is the case with tall fescue. In some of the more northern states, only one-fourth of the acreage or less is used to provide feed for beef animals. It was mentioned that persistence is a problem with growing orchardgrass in the more southern states, and several southern states reported essentially no acreage of orchardgrass.

There is a very small acreage of other cool-season perennial grass species in the southern region. Smooth bromegrass, wheatgrass, and hardinggrass are grown to a small extent in Texas and nearby states. Also, Kentucky bluegrass and timothy are used to some extent in the more northern states, but these are generally of minor interest to producers in most states in the south.

As far as cool-season annual grasses are concerned, ryegrass is the most widely adapted species in the southern region. The area of greatest usage of ryegrass is in the central and lower south. "Gulf, "Tetrablend 444" and "Magnolia" were reported as being the most commonly-grown varieties. In the southern region as a whole, probably around 80% or more of the ryegrass acreage is used to provide grazing for beef animals, although it also provides excellent grazing for dairy cows and other farm animals. Ryegrass is used to a small extent for hay, silage, or greenchop, and is frequently grown in combination with small grains and/or annual clovers - particularly when used in stocker calf programs. The practice of overseeding warm-season perennial pastures with ryegrass appears to be increasing in popularity in the lower south.

The small grains (rye, wheat, barley, and oats) are used extensively for forage throughout the southern region, but the extent of use of a given species varies according to area. Barley is most suited to be grown in the more northern parts of the region, with "Barsoy", "Keowee", "Volbar", and "Clayton" being some of the varieties most frequently used. The wheat acreage also tends to be concentrated in the upper part of the region, with "Arthur", "Abe", "Wakeland", and "Coker 68-15" being popular varieties. Rye is quite popular in the central and lower south, with "Wren's Abruzzi", McNair Vita Graze","Wintergrazer", and "Florida Black" being widely grown varieties. Oats, which are the least winterhardy of the small grains, are grown mostly in the lower south. "Florida 501","Coker 227", and "Elan" are some of the most widely grown oat varieties.

It was generally agreed that one of the primary problems involved in the production of cool-season grasses in the southern region is inadequate fertilization and liming. Representatives of most states indicated that, on the average, cool-season grass acreage received one-third or less of the recommended annual application of fertilizer and lime.

Ahring, R. M.
Research agronomist, Agricultural Research Service, Department of Agronomy, Oklahoma State University, Stillwater, OK 74074

Akin, Danny E.
Microbiologist, Richard B. Russell Agricultural Research Center, Agricultural Research Service, P.O. Box 5677, Athens, GA 30604

Amos, H. E.
Research physiologist, Richard B. Russell Agricultural Research Center, Agricultural Research Service, P.O. Box 5677, Athens, GA 30604

Ball, Donald M.
Extension agronomist, Department of Agronomy, 105 Extension Hall, Auburn University, Auburn, AL 36830

Barnes, R. F.
Staff scientist, forage and range, Agricultural Research Service, Nationa Program Staff, Room 411, Bldg. 005, Beltsville Agricultural Research Center, Beltsville, MD 20705

Barnett, O. W.
Asst. professor of forage legume pathology, Department of Plant Pathology and Physiology, Clemson University, Clemson, SC 29631

Burdick, Donald
Research chemist, Richard B. Russell Agricultural Research Center, Agricultural Research Service, P.O. Box 5677, Athens, GA 30604

Busbice, Thad H.
Professor, Crop Science Department, North Carolina State University, 1126 Williams Hall, Raleigh, NC 27607

Burson, B. L.
Research geneticist, Agricultural Research Service, P.O. Box 748, Temple, TX 76501

Burton, Glenn W.
Research geneticist, Agricultural Research Service, Department of Agronomy, Georgia Coastal Plain Experiment Station, Tifton, GA 31794

Carpenter, John C., Jr.
Superintendent, West Louisiana Experiment Station, P.O. Box 26, Rosepine, LA 70659

Ciordia, H.
Parasitologist, Cattle Parasites Research Laboratory, Agricultural Research Service, Experiment, GA 30212

Donnelly, E. D.
Professor of agronomy and soils, Auburn University, Auburn, AL 36830

Elkins, Charles B.
Soil scientist, soil and water research, Agricultural Research Service, 230 Funchess Hall, Auburn University, Auburn, AL 36830

Engelke, M. C.
Research geneticist, Agricultural Research Service, P.O. Box 748, Temple, TX 76501

Essig, H. W.
Professor of ruminant nutrition, Animal Science Department, P.O. Drawer 5228, Mississippi State University, Mississippi State, MS 39762

Evans, J. J.
Research physiologist, Richard B. Russell Agricultural Research Center, Agricultural Research Service, P.O. Box 5677, Athens, GA 30604

Evans, J. Kenneth
Extension specialist, soils, Department of Agronomy, University of Kentucky, Lexington, KY 40506

Evers, Gerald W.
Asst. professor of forage physiology, Texas Agricultural Experiment Station, P.O. Box 728, Angleton, TX 77515

Gibson, P. B.
Research agronomist, clover breeding and genetics, Department of Agronomy and Soils, Agricultural Research Service, Clemson University, Clemson, SC 29631

Haaland, R. L.
Asst. professor of agronomy and soils, Department of Agronomy, Auburn University, Auburn, AL 36830

Harris, R. R.
Professor of ruminant nutrition, 112 Animal Science Bldg., Department of Animal and Dairy Sciences, Auburn University, Auburn, AL 36830

Horn, Gerald W.
Assoc. professor, Animal Science Department, Oklahoma State University, Stillwater, OK 74074

Hoveland, C. S.
Professor, Department of Animal and Dairy Sciences, Auburn University, Auburn, AL 36830

Johnson, Wiley
Professor of plant breeding, 237 Funchess Hall, Department of Agronomy and Soils, Auburn University, Auburn, AL 36830

Jorgensen, N.
Professor of dairy sciences, Department of Dairy Science, University of Wisconsin, Madison, WI 53706

Langford, W. R.
Agronomist, Regional Plant Introduction Station, Agricultural Research Service, Experiment, GA 30212

McCaskey, T. A.
Assoc. professor of food microbiology, Department of Animal and Dairy Sciences, Auburn University Agricultural Experiment Station, Auburn, AL 36830

Moore, John E.
Assoc. professor of animal science, Nutrition Laboratory, Department of Animal Science, University of Florida, Gainesville, FL 32611

Ocumpaugh, W. R.
Asst. professor, Department of Agronomy, 2183 McCarty Hall, University of Florida, Gainesville, FL 32603

Palmertree, Hiram D.
Extension agronomist, agronomy, forage, pasture, and turf, Department of Agronomy, Mississippi State University, Mississippi State, MS 39762

Quesenberry, K. H.
Assoc. professor, Agronomy Department, University of Florida, Gainesville, FL 32603

Ray, Maurice L.
Professor of animal science, Department of Animal Science, University of Arkansas, Fayetteville, AR 72701

Richardson, W. L.
Asst. professor, Department of Agronomy, Oklahoma State University,

Stillwater, OK 74074
Robinson, E. L.
Research physiologist, Richard B. Russell Agricultural Research Center, Agricultural Research Service, P.O. Box 5677, Athens, GA 30604
Rodriguez-Kabana, R.
Alumni professor of botany and microbiology, Auburn University, Auburn, AL 36830
Rohweder, D. A.
Professor of agronomy and dairy science, Department of Agronomy, University of Wisconsin, Madison, WI 53706
Schank, S. C.
Professor of agronomy, Department of Agronomy, 2183 McCarty Hall, University of Florida, Gainesivlle, FL 32603
Shenk, J. S.
Assoc. professor of plant breeding, Department of Agronomy, Pennsylvania State University, University Park, PA 16802
Smith, Kenneth L.
Area agronomist, Texas A&M University, P.O. Box 220, Overton, TX 75684
Smith, Rex. L.
Assoc. professor, Department of Agronomy, University of Florida, Gainesville, FL 32603
Spooner, A. E.
Professor of agronomy, Department of Agronomy, University of Arkansas, Fayetteville, AR 72701
Taliaferro, C. M.
Professor of agronomy, Department of Agronomy, Oklahoma State University, Stillwater, OK 74074
Voigt, Paul W.
Research geneticist, Agricultural Research Service, P.O. Box 748, Temple, TX 76501
Watson, Vance H.
Assoc. agronomist, pasture and forage crops, Department of Agronomy, Mississippi State University, Mississippi State, MS 39762
Wiggins, Agee M.
Professor of veterinary medicine, Department of Large Animal Surgery and Medicine, Auburn University, Auburn, AL 36830
Wise, M. B.
Head, Animal Science Department, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061

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U. S. DEPARTMENT OF AGRICULTURE
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